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ON SOME MODERN SYSTEMS OF CUTTING METALS.*

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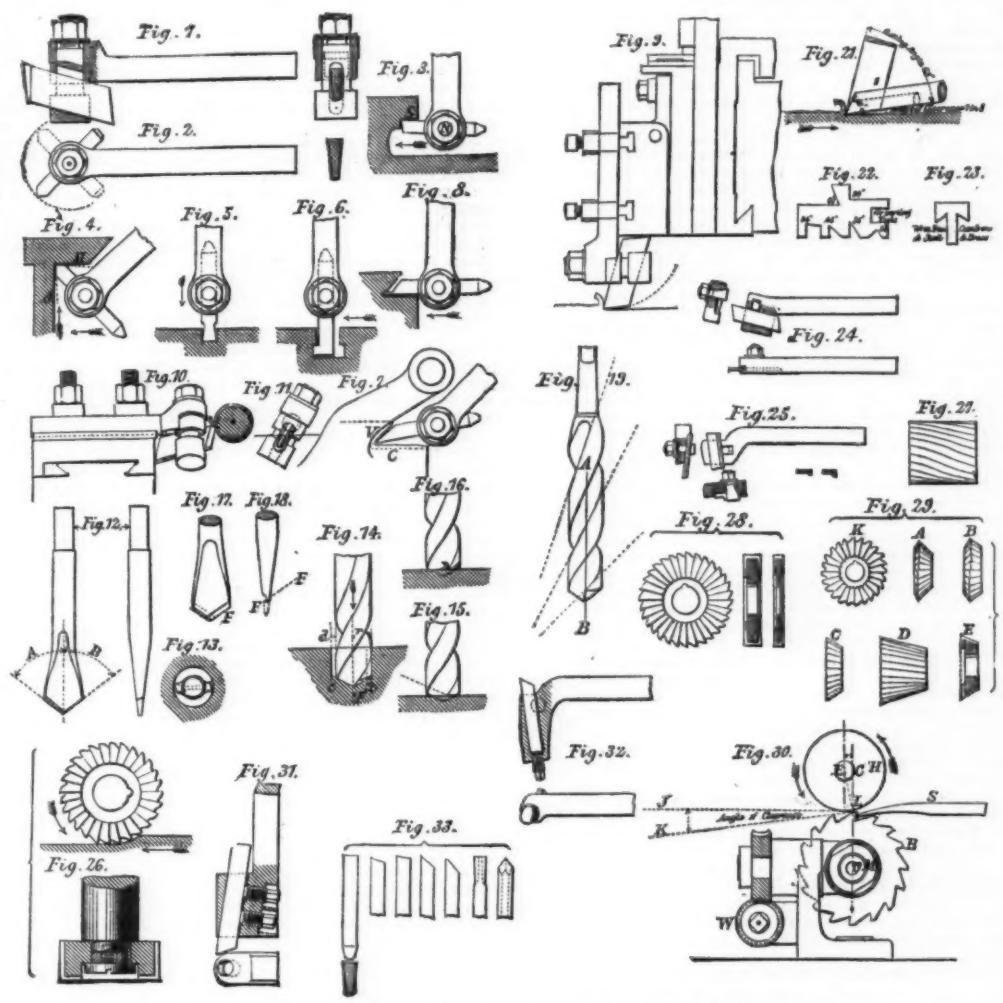
In this paper it is proposed to treat of some of the processes of cutting metals which the writer has adopted since he read a paper on "Tool-Holders" before the Institution (Proceedings, 1866, p. 288). The success of the round tool-holders then described has led to the further adoption of mechanical means of making and maintaining the tools used in various machines for cutting and finishing metals in their cold state. Such machines are commonly known by the term "machine tools," and comprise lathes, planing, shaping, and slotting machines, milling machines, drilling and boring machines, screwing and chasing machines, etc.

Tool-Holders and Cutters.—The former paper described mainly what have since become known as right and left hand round tool-holders. They are used in different machine tools principally for "roughing out," or, in other words, for rapidly reducing castings, forgings, etc., from their rough state nearly to their finished forms and dimensions. The tool-holders are so called from their cutters being made of round steel cut from the bar. Notwithstanding that they are very widely applicable, take heavy cuts, and do the bulk of all machine work in lathes, and in planing, shaping, and slotting machines, it was soon found that they could not compass the whole of the work required in the shops; and it was therefore necessary still to allow the use of some of the common forged tools in conjunction with the round tool-holders. This, however, was objectionable, as no positive rule could then be laid down to define what number of forged tools should be allowed to each workman; and it became apparent that the tool-holder system, in order to reach the highest degree of efficiency, must be made complete and independent in itself. This led to the designing of another tool-holder of the most general kind the writer could possibly devise, in the hope thereby to complete the system.

With this object in view, all the remaining forged tools then in use were collected together, and the swivel tool holder (Figs. 1 and 2) was schemed, with cutters so adjustable that they could not only be swiveled round and then fixed to any desired angle, but could be made to project at pleasure to any required distance in order to reach and cut into all sorts of difficult and awkward corners; in fact to machine any work which the round tool-holder could not finish. Two of the principal objects aimed at were to devise a system of cutters which should not require any forging or smithing, and yet should be capable of being adapted, by the simplest possible means, and by grinding the ends only, to all forms which the round cutters would not admit. The special section of steel decided upon was a sort of deep V section, the lower part of which is slightly rounded, as shown in Fig. 2. The angles of the sides give the same amount of clearance (1 in 8) as that given in the round tool-holders, and this same angle of clearance is given to the ground parts. The section of the swivel cutter is very deep, in order to obtain ample strength in the direction of the pressure it has to support when cutting. The angle in Fig. 1 is common to every swivel tool-holder. In the cutter for the round tool-holder two angles had been fixed upon as standards, one to cut all kinds of wrought metals, the other all cast metals. To avoid complication, however, in the swivel tool-holders one cutting angle was fixed upon for all metals, and applied to all cutters. The angle selected is one slightly differing from that of the round cutters, but is that which worked the best in practice. The cutters of the round tool-holder system are found most advantageous in producing and finishing standard-size round corners in journals of shafts, etc., and in other cases, where the engineer of the present day is anxious to preserve all the strength he can in the parts he is constructing; but there are still cases where square, angular, or undercut surfaces must be produced, as illustrated by Figs. 3 to 8. These are front views showing the tool-holders at work planing or shaping. They are supposed to be traveling forward, or the work to be moving in the opposite direction; and the arrows in each figure indicate the direction in which the tool-holder is being fed at each stroke of the machine to take the next cut.

Fig. 4 shows the mode of planing the under horizontal surface of a lathe bed. The cutter shown in use is ground to an angle of 86 deg., or 4 deg. less than a right angle, and thus has a clearance of 2 deg. at each side when cutting either horizontally or vertically. The cutter is very general in its applicability, and is devised so as to finish with one setting both the vertical surface, A, and the horizontal surface, H, without the necessity of disturbing the cutter in any way. The ordinary system is to use at least two tools for roughing out, and two for finishing, on two surfaces at right angles with each other.



MODERN TOOLS AND CUTTERS FOR METALS.

Fig. 3 shows the method of planing in a very limited space the under horizontal surface, S; the corresponding surface is planed afterward, without disturbing the tool-holder, by simply swiveling the cutter half-way round in the holder and securing it there by the nut, N.

Fig. 7 shows a swivel tool-holder clearing without difficulty a boss which projects and would be very much in the way of any ordinary tool. The cutter in this case planes not only the horizontal surface but the vertical surface also, with one setting and without being disturbed in the tool-box.

Fig. 5 shows the method of cutting a vertical slot in a horizontal surface of metal. The cutter in this case is called a parting tool.

Fig. 9 is a side elevation of this same cutter, showing the cutting angle.

Figs. 6 and 8 are tool-holders with cutters of rather special forms. The former is shown planing out or undercutting a T-shaped slot, and the latter is planing out a small rectangular clearance corner.

Figs. 10 and 11 show a swivel tool-holder with a round shank, such as is used on the slide-rest of a screw-cutting lathe, for cutting square threads. It is carried on a wrought iron or steel block, provided with a groove, semicircular in section, in which the round shank of the tool holder lies, and is clamped down in the usual way. The cutters for cutting out the spaces between the square threads are of a very simple form, and by the aid of this tool-holder any tool of the correct width of the space will cut either right hand or left hand screws, no matter whether they are single threads, double threads, or any other. To cover the same ground with forged tools, no less than six expensive cutters would be required, each one forged from square steel, and carefully filed up and hardened. With the tool-holder only one cutter is required, and it costs, probably, not more than 10 per cent. of one of the six forged tools, while it maintains its size much better, and consequently lasts much longer. It also takes about twice the weight of cuttings per hour as compared with an ordinary forged tool. This system is useful where many screws of odd forms and pitches are required; but where there are sufficient numbers to be cut, special chasing lathes are far preferable to ordinary screw-cutting lathes, as they will do about six times as much chasing of V threads, or cutting of square threads, as can be accomplished in the ordinary lathe in the same time. Instead of carrying one chaser, the chasing lathes carry, in a chasing apparatus, three or four chasers; and these have their threads, whether square, V, rounded, or any other form, cut in their places by aid of a master tap. They are then tapered at the mouths, backed off, and hardened ready for work. The number of shavings cut simultaneously from a screw by this process varies from twelve to twenty-four, according to the size, strength, and pitch of the thread. Screws up to 6 in. diameter can be very rapidly cut by this system, on which very much more might be said if time permitted. A few screws cut by this process are exhibited.

When the two systems—the round and the swivel tool-holder—are worked in conjunction with each other, their universality of application is so thorough that almost every difficulty is met; and it was only in the case of paring and shaping articles in the slotting machine that two modifications had to be made in the holders, the same cutters being still applicable.

The capstan bed chasing lathes made by the writer's firm have now become much used; and as a large amount of their work is done upon black bars of iron, steel, or other metals, each of which has to be finished at its extremities and cut or parted off, it was found advisable to make one special tool-holder, Fig. 25, to carry tools of the correct sections to produce the desired shapes for the ends; the tedious and unreliable process of turning the ends with hand-turning tools is thus avoided. Each cutter is of absolutely the same section throughout its entire length, and the resharpening is done by grinding the end of the cutter only, so that it can only produce the same standard form as long as it lasts, that is to say till it is ground too short to be used any longer. The parting off might have been accomplished by the swivel tool-holder; but a special form, Fig. 24, is found to be more convenient in parting off close up to the chuck or lathe spindle.

To produce a maximum amount of cutting in a minimum space of time, there are two main points which must be carefully attended to. These seem to be applicable to all cutters for cutting metals, whether they happen to be those fixed rigidly in tool boxes, as in turning lathes, planers, shapers, slotters, etc., or those which cut as they revolve, as milling-cutters, twist-drills, boring-bits, etc.

These two important points are:

First, the angle of the cutting surface (or cutting angle), Fig. 21, *i. e.*, that surface which removes the shavings of metal, and upon which the pressure of the cut comes, as shown by the arrow.

Secondly, the angle of the clearance surface (or clearance angle), *i. e.*, that surface which passes over the surface of the metal which has been cut, and does not come in contact with the metal at all.

To produce the best results, and to insure the utmost simplicity, it is important that these two angles be correctly constructed in the first instance. The best measure for both angles has been arrived at from actual practice and a series of experiments. When once obtained and started with, they should not alter by use, but always remain constant, if the greatest amount of cutting efficiency is to be achieved. When aided by a mechanical system of regrinding, and the

* Paper read before the Institution of Mechanical Engineers.

use of standard angle gauges, Figs. 22, 23, there is no difficulty in maintaining the exact angles. The only changes which take place are that the cutters in tool-holders become gradually shorter by grinding, and that milling cutters during a long period of time become very gradually smaller in diameter by the process of resharpening them on a fine emery wheel. In the case of the tool-holders, as already explained, the cutting angle is maintained by the system of regrinding, and the tool-holder itself always maintains the clearance angle. The system is thus simplified, as will be clearly understood when it is remembered that each one of the tool-holder cutters (no matter of what description) is ground on its end only. The section is thus never altered, no smithing or alteration in form is necessitated, and consequently no repairing has to be done in the smith's shops. The objects aimed at have been:

1. To produce the highest class of workmanship, by providing the best known form of cutters, carefully made, and capable of having the cutting edges accurately reground, so that the surfaces of the machined work may be produced direct from the cutters so highly finished that no hand-work could possibly improve them. All the turning of wrought iron, for instance, is so perfectly finished that there is no necessity to polish it by means of emery or emery cloth.

2. To make all the cutters so free from complication, and simple to keep in order, that no difficulty or error may take place in regrinding them.

3. Since finely-polished surfaces cannot be obtained without the most perfect cutting edges, to make all cutters not only of the best steel, but with their cutting edges most accurately and carefully ground up, in almost all cases by mechanical means. The durability of the cutters, from their construction and high class of material, is very great, and they are thus capable of removing a great weight of metal in a given time.

The grinding or resharpening of all cutting edges is reduced to the greatest simplicity; and only three descriptions of machines are requisite for this purpose. They are all arranged to grind mechanically; that is to say, the cutters while being ground are carried and pressed on the grindstone or emery wheel by mechanism. The requisite forms and angles are also obtained by mechanism, it being found in practice that sufficient accuracy cannot be secured by hand grinding.

The machines are as follows:

1. A grindstone with slide rest, for grinding all the cutters used in tool-holders.

2. A twist-drill grinder; this also is by preference a grindstone, with mechanism for holding and guiding the twist-drills. A machine with an emery wheel in place of the stone is also used for the grinding of twist-drills, with much the same mechanism for carrying the drills. In practice, however, the stone grinds about double the number of drills per day, and with less risk of drawing the temper. Both stone and emery wheel are run at a high speed, and used with water.

3. A small but very complete machine (Fig. 30) for regrinding milling cutters. In this case gritstone does not answer, and the grinding wheels are obliged to be emery or corundum. They are very small in diameter, and many of them are exceedingly thin, and so delicate in form that if made of gritstone they would rapidly lose their shapes. They are run at a high speed, and are turned into form while revolving by means of a diamond. A milling cutter will work for a day, and in many cases for two days, without showing signs of distress.

Before the cutting edges are visibly blunted, but as soon as the sense of touch shows their keenness to be diminished,* the cutter should be put into this machine; and the probability is that not more than one-thousandth of an inch need be ground off each tooth, before it is restored again to a cutting edge almost as fine as that of a wood chisel. Each cutting edge, or, in other words, each tooth of the milling cutter, is only passed rapidly once or twice under the revolving wheel, which is itself of very fine emery. It can therefore be readily understood how delicate an operation this is, and why emery alone will answer for it.

In order to maintain the correct forms and angles of all cutters for tool-holders, sheet steel angle gauges (Fig. 22) are provided, and the process of grinding is thus reduced to a complete and exceedingly simple system. In well-regulated shops a young man is selected to work each machine for cutter grinding; and in practice each man so engaged can keep a works employing 150 men (exclusive of moulders and boiler makers) well supplied with all the necessary cutting tools from day to day. A very great saving is thus effected, as no machine need ever stand idle for want of cutters.

Take for instance an engineering works employing 250 men. The requisite number of improved grinding machines, with special mechanical appliances, is as follows:

Two patent grindstones for resharpening cutters mechanically.

One patent twist-drill grinder for resharpening twist-drills mechanically.

One improved cutter-grinder with small emery wheel, for the resharpening of cutters used in milling machines.

To follow the system out satisfactorily the man working at the grindstone goes round to each machine every morning, collects together those cutters which have been blunted by use the previous day, carries them to his grindstone, resharpens them, and distributes them again to each machine; which is thus kept well stocked with an ample number of cutters, always ready for immediate use.

The cutters for tool-holders do not require any repairing in the smithy; consequently that operation, which is costly in so many ways, is avoided, and jobbing or tool smiths with their strikers are almost entirely dispensed with.

For resharpening the cutters, a rule is made that when the grinder meets with cutters which are not as hard at their cutting points as they ought to be, he puts them on one side, and periodically, say once each fortnight, he sends the lot into the smithy for the end of each to be retempered. This is a very inexpensive operation. They are placed in a small oven by dozens and very slowly heated up to a dull red; the end of each cutter is then plunged into a perforated iron box, the bottom of which is covered with the required depth of water, to harden the cutter to the proper distance from its point. The cutters are left standing in a nearly vertical position in the box of water, until they have gradually cooled down sufficiently to be removed. They are then sent to the grindstone, reground, and given out with the other cutters to be again used in the different machines. With steel of the highest quality for the cutters it is most important to keep it out of the smith's hands entirely if possible. That object is here attained, the cutters never going to the fire except for rehardening. During the life of a cutter it only sees the fire probably six times.

As the weight of each cutter is small, not probably more than from one-fifteenth to one-twentieth that of a forged tool used for the same purpose, the outlay for best tool steel is not heavy; and the engineer is not tempted to purchase any but that of the highest quality. With such steel, especially when used in the best manner, each machine is capable of cutting at a high rate of speed, and the cuts may be coarser than those ordinarily taken. When the swivel tool-holders were first used on planing machines, cutting slots one inch broad into solid castings, it was found that two teeth of the feed could be used at each stroke. Previously a forged tool of the same breadth, ground to form by the planer to the best of his ability, had been used in the same machine; but he found, on trial from time to time, that it was impossible to use more than one tooth of the feed; or, in other words, the tool-holder cut a given depth into the metal in half the time of the forged tool.

Again, when the swivel tool-holders were first used in cutting square-threaded screws, the utmost the lathe could do with forged tools was to take four degrees of feed at each cut, as indicated by the micrometer feed-wheel. The tool-holder, on the other hand, took seven degrees of feed in the same lathe, doing the same work, and producing quite as good or a better finish, with the same expenditure of steam power.

The cutters for the swivel tool-holders can not only be made at the outset, but also constantly maintained, at the best and most efficient angles which practice can teach; it therefore follows that a very much better class of machine work can be produced. The finished surfaces obtained from the tool-holders show a striking superiority over those from forged tools, especially when in the latter the angles are ground by hand by each man or boy working a machine. The tendency then is to grind the cutters to all sorts of incorrect forms, which more or less tear the surface of the machined work, and leave bad finishes, such as require a considerable amount of hand labor bestowed upon them afterward, in filing, scraping, and polishing.

Again, the tool-holders have led up to a considerable extension of what is called broad finishing, in planing, turning, shaping, slotting, etc.

Broad-cutting feeds, varying from $\frac{1}{8}$ in. to $1\frac{1}{8}$ in. in width, are very commonly taken by the swivel tool-holders, and more accurate surfaces produced than with finer feeds. The advantages in point of time saved are very great; the time occupied in finishing by broad-cutting being from one-twelfth to one-twentieth of that consumed by finishing with ordinary feeds and in the usual manner.

The width of broad-cutting can be increased to any desired limit, and there have been special cases where it has been advantageous to take thin shavings 3 in. to 6 in. in width.

The principal limits to broad-cutting are as follows:

1. The power of grinding the cutting tool to a sufficiently straight or true cutting edge; the best plan, of course, being to do this by mechanical means.

2. The securing a sufficient stability in the machine tool to hold the broad-cutter so rigidly up to its work that neither the cutter itself nor the work may spring away, and that no jarring or injurious vibration may be produced, and impart its evil effect to the finished surface.

3. The securing of sufficiently accurate work to answer the purpose for which it may be required; for instance, the piece of work planed or turned by this process may be a portion of a large railway bridge, where absolute accuracy is not required, or it may be some portion of a machine tool, where the utmost accuracy is needed, or, again, some portion of an engine, where the builder is anxious to obtain all the accuracy which can possibly be produced direct from the machine tool.

Twist-drills.—During the last thirty years many attempts have been made to introduce a better system of drilling and boring; and on this subject very much might be written if time permitted. Many engineers have used square bar steel, which the blacksmith has twisted, and then flattened at one end to form a drill. The object of the twisted stem was to screw the cuttings out of the hole, and to some extent this succeeded, but not perfectly. The twisted square section revolving in the round hole had a tendency to crush or grind up the cuttings; and if they were once reduced to powder it was difficult (especially in drilling vertically) for the drill to lift the powdered metal out of the hole.

In most cases the lips of the drills were of such form that the cutting angle, or face of each lip, which ought to have been about 60°, Fig. 21 (see previous page), was 90°, or even still more obtuse; this being an angle which would scrape only, but could hardly be expected to cut sweetly or rapidly.

Again, there were attempts to make the cutting angles of the two lips of much the same number of degrees as that given by the twist itself in a good twist drill. This was done by forging or filing a semicircular or curved groove on the lower face, F, of each lip, Figs. 17 and 18. For a short time lips thus formed cut fairly well, but a very small amount of regrinding soon put them out of shape, and made them of such obtuse cutting angles that good results could no longer be expected from them; and to be constantly sending such drills to the jobbing or tool smith, and then to the fitter to file into form again before they were rehardened, was found to be too tedious and too expensive. Again, to arrive at the best results in drilling, each of the cutting lips should make the same angle with a central line taken through the body of the drill; in other words, the angles, A and B, Fig. 12, should each have exactly the same number of degrees, say 60°. The clearance angles also should be identical, and the leading point, P, should form the exact center point of the drill. From practice it is found that if these proportions are not correct, the drill cannot pierce the metal it is drilling at more than about half the proper speed, and the hole produced will also be larger than the drill itself, as will be exemplified a little later on. To give an idea of the excessive accuracy which must be imparted to a twist-drill, we must bear in mind that even a good feed is only $\frac{1}{100}$ in. to each revolution; and as two lips are employed to remove this thickness of metal, each lip has only half that quantity to cut, or $\frac{1}{200}$ in. This $\frac{1}{200}$ in. is as much as can be taken in practice by each lip in drills of ordinary sizes.

It will therefore be readily understood that if one lip of a drill stands before the other to the extent of $\frac{1}{100}$ in. only, the prominent lip, or portion of a lip, will have to remove the whole thickness of the metal from the hole at each turn. The lip of the drill will not stand such treatment; and it is therefore obvious that if this were attempted the prominent lip would either break or become too rapidly blunted. To get over these difficulties, the driller would no doubt reduce his feed by one-half, or to $\frac{1}{100}$ in. per turn, which would mean about half the number of holes drilled in a given time.

This nice accuracy, although absolutely required, cannot be produced by hand-grinding; neither can a common drill, having a rough black stem more or less eccentric, be ground accurately, even by aid of a grinding machine with mechanism for holding it. To grind any drill accurately, it must be concentric and perfectly true throughout with the shank, as that part has to be held by the drill-grinding machine. If the drilling is to be done in the most rapid manner, in other words, at the smallest cost, and if the best class of work is also desired, it seems certain that a twist-drill, with all the accuracy which can possibly be imparted to it in its manufacture, and the greatest care employed in the resharpening, is the only instrument which can be employed.

About a quarter of a century ago both Sir Joseph Whitworth and the late Mr. Greenwood, of Leeds, made some twist-drills; but it is to be presumed that a large amount of success was not achieved with them, and for some reasons the system was not persevered with. After that period the Manhattan Firearms Company in America produced some beautifully finished twist-drills. Though the workmanship in these was of a superior description, the drills would not endure hardship. It was found that the two lips were too keen in their cutting angles, and that they were too apt to drag themselves into the metal they were cutting, finally to dig in and to jam fast, and to twist themselves into fragments. Mr. Morse then took the matter up, and by diminishing by about 50 per cent. the keenness of the cutting lips of twist-drills, made a great success of them. He used the grinding line, A B, Fig. 19, and an increasing twist. In such a drill, of the standard length, and before it is worn shorter by grinding, the twist is so rapid toward the lips that the angle they present, or what has been already referred to as the angle of the cutting surface, is very nearly the same as that the writer had previously established for cutters cutting metals, as in Fig. 21.

If, however, the angle of twist is made to increase toward the lips, it will of course decrease toward the shank, as in Fig. 18. The shorter the drill is worn, the more obtuse the cutting angle becomes, and the less freedom will it have; supposing, of course, that the angle, when the drill was new, was the most efficient. Suppose this decrease of twist were carried still further by lengthening the drill, a cutting angle of 90° would eventually be arrived at. The old common style of drill usually has a cutting edge which is so obtuse as not to cut the metal sweetly, but on the contrary to have more of a tearing action, and thus put so much torsional strain on the drill that fracture is certain to take place, even if what the writer would now consider a moderate feed was put on by the drilling machine.

It is therefore obviously advantageous to adopt from the first the best cutting angle for all twist-drills, and to preserve this same angle through the whole length of the twisted part, so that, however short the drill may be worn, it always presents the same angle, and that the most efficient which can be obtained. This cutting angle is easy to fix, and becomes an unalterable standard which will give the best attainable results. This has been adopted at the Gresley Works, Manchester, and of course applies to both lips.

A common drill may "run," as it is usually termed, and produce a hole which is anything but straight. This means that the point of the drill will run away from the denser parts of the metal it is cutting, and penetrate into the opposite side, which is soft and spongy. This is especially the case in castings; where, for instance, a boss may be quite sound on the one side, while on the other a mass of metal may be full of blow holes, or so drawn away by contraction in cooling as to be very soft and porous. In such cases it is perfectly impossible to prevent a common drill from running into the soft side. This sort of imperfect hole is most trying to the fitter or erecter, and if it has to be tapped, to receive a screwed bolt or stud, is most destructive to steel taps. The taps are very liable to be broken, and an immense loss of time may also take place in attempting to tap the hole square with the planed face. A twist-drill, on the other hand, from its construction is bound to penetrate truly, and produce holes which are as perfect as it is possible to make them.

The next important step in twist-drills has been to fix a standard shape and angle of clearance for both lips, which should also give the best attainable result. This angle might be tampered with if the regrinding were done by hand, and too much or too little clearance might easily be imparted to the drill from want of sufficient knowledge on the part of the workman. If too little clearance, Fig. 15, or in some cases none at all, is given to the drill, the cutting lips then cannot reach the metal, consequently they cannot cut. The self-acting feed of the drilling-machine keeps crowding on the feed until either the machine or the drill gives way. Usually it will be the latter.

Again, if too much clearance is given, Fig. 16, the keen edges of the lips dig into the metal and embed themselves there, and of course break off.

The grinding line, A B, Fig. 19, was introduced in the States to assist the operator in keeping both lips of the drill identically the same. To arrive at this, however, is more than can be accomplished by hand grinding, as not less than three points have to be carefully watched, viz.:

1. That both lips are exactly the same length.
2. That both make the same clearance angles.
3. That both make the same angle with the center line on the body of the drill.

If these are not attended to, the drill lips may for instance be both ground so as to converge exactly to the grinding line at the point or center of the drill, and may still be of such different lengths and angles as to produce very bad results in drilling.

Much ingenuity has been expended on machines for the grinding of the two lips with mechanical accuracy.

The one which has been the most successful in the United States has three motions, ingeniously combined with each other. So many motions, however, entail complication; and this, added to a system of holding the drill which was not sufficiently reliable, failed to produce the extreme accuracy it is requisite to impart to the two angles.

The grinding line, too, is found to be more or less a source of weakness. It is therefore advisable to dispense with it if possible; and where a good twist-drill grinding machine is used, the grinding line is seldom or never looked at, and in that case is useless. If it is still desirable to have grinding lines (as in some cases where hand grinding has to be relied upon), they should be made as faint as possible, and not cut deeply into the thin central part of the drill, so as to weaken it.

Fig. 14 is drawn exaggerated, in order to show the ill effect of grinding one lip of a drill longer than the other.

*The sense of touch, in passing the finger over the cutting edges, conveys the idea of slight bluntness better than it can be detected by the eye.

COMPARISONS OF TIME OCCUPIED IN ROUGHING-OUT AND FINISHING METAL SURFACES IN MACHINE TOOLS.

Class of Work.	Kind of Metal.	Size and Number of Surfaces.	Shape o Surface Machined.	Time occupied by				Remarks.
				Milling Machine.	Planing Machine.	Shaping Machine.	Slotting Machine.	
Lower part of 4½ in. pedestal	Cast iron.	18 in. by 6 in.	Flat under-surface.	One cut over, 7¾ minutes.	One cut over, 11¾ minutes.			
Ditto	Cast iron.	18 in. by 6 in.	Ditto.	2 cuts, 16 minutes.	2 cuts, 22 minutes.			
Ditto	Cast iron.	Two 6 in. by ⅝ in. Two 6 in. by ½ in.	Vertical surfaces. Horizontal surfaces.	4½ minutes.	....	38 minutes.	....	In the milling machine all these four surfaces were roughed out and finished at one pass, whereas four passes are needed in the shaping machine.
Ditto	Cast iron.	Two 2¾ in. dia. each.	The upper surface of two bosses.	2 minutes each.	....	3½ minutes.		
Cap for ditto	Cast iron.	One 1⅝ in. dia. Two 2¼ in. dia.	Horizontal surface Ditto.	1½ minutes. 3 minutes each.	....	...	....	Cannot be done except in a milling machine.
Ditto	Cast iron.	Two 6 in. by ⅝ in. Two 6 in. by ½ in.	Horizontal surface. Vertical surface.	4½ minutes.	....	38 minutes.		
Plate	Wrought iron.	6¼ in. by 3 in.	One flat surface.	Finished in 6 minutes at one cut.	...	13 min. roughing 3 " finishing 16 " total.	....	The milled surface quite as good as the shaped.
End of flat joint, as in Fig. A	Wrought iron.	One convex and two concave surfaces.	...	18 minutes roughing and finishing.	....	....	44 minutes roughing and finishing.	
Plate	Mild steel.	2¾ in. by 6 in.	One flat surface.	5½ minutes finished at one cut.	..	13 min. roughing. 7 " finishing. 20 " total.		
Surfaces of pawl, as in Fig. B	Mild steel.	Three curves.	....	18 minutes roughing and finishing on curves.	....	....	36 minutes roughing and finishing curves.	
End of a reversing lever	Mild steel.	....	Two flat surfaces and two curves.	17 minutes.				

A simple and efficient twist-drill grinding machine was so much needed that within the last three years the writer has designed one. The twist-drill in this machine has only one motion imparted to it, to produce the two lips of each drill as perfect facsimiles of each other and with the desired amount of clearance. Many of these machines are now at work. That the drills ground by them are accurate is proved by the holes drilled being so nearly the size of the twist-drill itself that in many cases the drill will not afterward drop vertically through the drilled hole by its own gravity; in other words, the hole is no larger than the drill which has drilled it.

It is not generally known that this is the most severe test that can be made of the accuracy of regrinding, and of the uniformity of all parts of the twist-drill.

One of the smallest sized machines is exhibited. The largest machine grinds drills 3 in. in diameter.

The whole of the drilling in many establishments is now done entirely by twist-drills. Since their introduction it is found that the self-acting feed can be increased about 90 per cent.; and in some engineering works the feeds in some machines have been increased by fully 200 per cent., and consequently three holes are now being drilled in the same time that one was originally drilled with the old style of drill, and with old machines.

It may be interesting to give a few results out of numerous tests and experiments made with twist-drills. Many thousands of holes ½ in. in diameter and 2¾ in. deep have been drilled, by improved ½ in. twist drills, at so high a rate of feed that the spindle of the drilling machine could be seen visibly descending and driving the drill before it. The time occupied from the starting of each hole, in a hammered scrap iron bar, till the drill pierced through it, varied from 1 minute 20 seconds to 1¼ minute.

The holes drilled were perfectly straight. The speed at which the drill was cutting was nearly 20 ft. per minute in its periphery, and the feed was 100 revolutions per inch of depth drilled.

The drill was lubricated with soap and water, and went clean through the 2¾ in. without being withdrawn; and after it had drilled each hole it felt quite cool to the hand, its temperature being about 75 deg. It is found that 120 to 130 such holes can be drilled before it is advisable to resharpen the twist-drill. This ought to be done immediately the drill exhibits the slightest sign of distress. If carefully examined, after this number of holes has been drilled, the prominent cutting parts of the lips, which have removed the metal, will be found very slightly blunted or rounded, to the extent of about $\frac{1}{100}$ in.; and on this length being carefully ground by the machine off the end of the twist drill, the lips are brought up to perfectly sharp cutting edges again.

The same sized holes, ½ in. in diameter and 2½ in. deep, have been drilled through the same hammered scrap iron at the extraordinary speed of 2¾ in. deep in one minute and five seconds, the number of revolutions per inch being 75. An average number of 70 holes can be drilled in this case before the drill requires resharpening. The writer considers this test to be rather too severe, and prefers the former speed. The drills in both cases were driven by a true-running drilling machine spindle, having a round taper hole, which also was perfectly true; and the taper shank and body, or twisted part of the drills, also ran perfectly concentric when placed in the spindle, or in a reducer, or socket having a taper end to fit the spindle. When the drills run without any eccentricity, there is no pressure, and next to no friction on the sides of the flutes; the whole of the pressure and work being taken on the ends of the drills. Consequently they are not found to wear smaller in diameter at the lip end, and they retain their sizes, with careful usage, in a wonderful manner. The drills used were carefully sharpened in one of the twist-drill grinders mentioned above.

In London upward of 3,000 holes were drilled ⅝ in. in diameter and 3½ in. deep, through steel bars, by one drill without regrinding it. The cutting speed was, in this instance, too great for cutting steel, being from 18 ft. to 20 ft. per minute; and the result is extraordinary.

Many thousands of holes were drilled ⅛ in. in diameter, through cast iron $\frac{1}{10}$ in. deep, with straight-shank twist-drills gripped by an eccentric chuck in the end of the spindle of a quick-speed drilling machine. The time occupied for each hole was from nine to ten seconds only. Again, ¼ in. holes have been drilled through wrought copper, 1⅜ in. thick, at the speed of one hole in ten seconds.

With special twist-drills, made for piercing hard Bessemer steel, rail holes, ⅞ in. deep and ⅝ in. in diameter, have been drilled at the rate of one hole in one minute and twenty seconds, in an ordinary drilling machine. Had the machine been stiffer and more powerful, better results could have been obtained. A similar twist-drill, ⅞ in. in diameter, drilled a hard steel rail ⅞ in. deep in one minute, and another in one minute ten seconds. Another drill, ⅝ in. in diameter, drilled ¾ in. deep in thirty-eight seconds, the cutting speed being 22 ft. per minute. The speed of cutting rather distressed the drill; a speed of 16 ft. per minute would have been better. The steel rail was selected as being one of the hardest of the lot.

Milling.—The writer considers milling the most important system used in the cutting of metals, and would willingly dwell more upon it if time would permit. He will, however, confine himself to giving a few particulars as to the time occupied, and the finish produced by milling machines, in comparison with the planing machine, the shaping machine, and the slotting machine. It is found practicable, and in most cases it is exceedingly advantageous, to finish (or as it is usually termed to "machine") almost every class of work, such as is now usually finished by planing, shaping, or slotting machines, in one or other of the numerous kinds of milling machines already in use. It may not be generally known that in this class of machine, milling cutters are being used of diameters ranging from 20 ft., used for heavy engine work, down to ⅛ in. or ⅛ in., used principally for the intricate work required in sewing machines, small arms, etc.

By the former, the work done is what is known as face-milling; the mill itself is somewhat similar to a large lathe faceplate, and the several cutting portions are steel tools inserted into and firmly secured to it by a series of set screws or keys. On the other hand, the milling cutters of the small sizes, from ⅛ in. up to about 8 in. in diameter, are made from solid blocks of cast steel, or blanks, as shown in Fig. 29.

The term milling is more generally understood in the United States than in this country. It means the cutting of metals by aid of serrated revolving cutters, each having a number of cutting teeth. Milling cutters have been used in this country for many years, but until recently with only a limited amount of success, owing to the expense and difficulty of producing their cutting edges and keeping them in order. This was next to impossible before the introduction of a machine, with a small emery wheel and compound slides, etc., for carrying the milling cutter while being resharpened. Hence in the old system of milling, which did not permit of the resharpening of the hard teeth, the results were, that after much expense and time had been bestowed on a cutter (including a quantity of hand labor spent upon it while in its unhardened state), the whole was as it were upset by the process of tempering; the accuracy which had previously been imparted to it being usually quite destroyed by the action of the fire and sudden cooling. In some cases the cutter would be found lightly warped or twisted; in others it would be oval or eccentric; and most frequently, when set to work on a truly-running mandrel in the milling machine, not more than one-third of the number of its teeth were found to be cutting at all, the others not coming in contact with the work. This really meant that not more than two-thirds of the proper feed per revolution could be applied, and not more than two-thirds of the proper work produced. Nor was this the only drawback; the quality of the workmanship produced by such a milling cutter was not of the best, and deteriorated hourly from blunting and wear. Such a cutter would probably not work for more than two whole days before it would require to be again softened by being heated red hot and allowed to cool gradually. The expensive and unreliable process of resharpening by hand-filing had to be gone through again once more, then the retempering, which caused the cutter to again become warped, swelled, or eccentric; and each time it was subjected to the heat of the fire, it ran the risk of being destroyed by cracking when plunged into the cold bath.

It is necessary now to describe the modern system of making and maintaining the improved milling cutters. A cast-steel forging, or blank, as it is usually styled, is bored, and then turned to its proper shape in a lathe. The teeth are then machined out of the solid to their required forms, in a universal milling or other machine. This work is so accurately produced, direct from the machine, that no expensive hand labor need be expended upon the milled cutter, which is taken direct from the milling machine to the hardening furnace, and tempered. The hole in the center of the cutter is then carefully ground out to standard size, so that it may fit naturally and without shake both on the mandrels of the grinding machine and on that of its own milling machine.

The cutter or mill, B, Fig. 30, is now placed on the mandrel, M, of the small cutter-grinding machine; the mandrel itself is adjusted by means of a worm, W, and wormwheel, C, to its required angular, vertical, or horizontal position, and each tooth is ground or resharpened by passing it once rapidly forward and under the small revolving emery wheel, H. The mandrel fits easily into the cutter which is being ground so that the latter may be readily turned round by the thumb and finger of the operator.

The exact mode of setting such cutters is as follows: The clearance angle, J L K, on each tooth is obtained and maintained by the emery wheel, H, one of which is exhibited. The clearance is obtained by adjusting the center, E, of the emery wheel, H, a short distance horizontally to the left of the vertical line through the center, O, of the milling cutter. The shorter this distance, E C, the less the amount of clearance imparted to each tooth of the milling cutter, A. The lower line, L K, is a tangent to the circumference of the milling cutter, drawn from the point of contact, L; and the upper line, L J, is a tangent to the emery wheel from the same point. The angle formed by these two lines is the angle of clearance.

Each tooth is held in its correct position by means of a stop, S, while the milling cutter is rapidly passed once forward and backward under the emery wheel. As will be seen by the arrows, the tendency of the emery wheel is to keep the cutting edge which is being ground close up against the stop, S. There is no more difficulty in grinding spiral cutting edges than straight ones; and the face and conical cutters can also be ground correctly, and with the same amount of ease.

Milling cutters are made of the required forms to suit the various shapes they are intended to produce; and all the ordinary forms can be used in any milling machine either of horizontal or vertical class.

The face-milling cutters, Fig. 26, are of disk form, and are among the most useful. They are constructed to cut on one face and on the periphery, and produce a very perfect finish, especially on cast iron. This form is also very useful for stepped work, which, even when not of the simplest form, can be readily and reliably finished to standard breadths and depths; so that the pieces may be interchangeable, and fit together without the slightest shock, just as they leave the machine, and without any hand labor bestowed on them.

Another ordinary but very useful form is the cylindrical cutter, Fig. 27, with teeth cut spirally over its circumference. This is largely employed for cutting flat, vertical, or horizontal surfaces, for finishing concave and convex curves, and for complicated forms made up of straight lines and curves. With this spiral arrangement of the teeth, and with reliable means of regrinding or resharpening them, very high-class machine work can be produced. Some experiments have been made by cutting a spiral groove or thread into the outer surface of one of this class of mill, and thus reducing the aggregate length of its cutting surface. The results appear to be practically as follows: If half the length of cutting edges are dispensed with, only about half the maximum feed per revolution of the cutter can be applied by the machine; if three-quarters of the length of the cutting lips are left intact, three-quarters only of the aggregate feed can be used; and so on in the same proportions.

Other mills, again, are made in the form of small circular saws, varying from ¼ to 1½ in. or more in thickness. The teeth in some of these are simply cut around the circumference; others have these teeth extending some distance down each side, their edges radiating from the center of the mill, as in Fig. 28. Toward the center they are reduced in thickness so as to clear themselves. These cutters are very useful for a great variety of work; for instance the cutting of key-ways, parting off or cutting through pieces of metal,

and making parallel slots of various widths, for the broader of which two or more cutters may be used side by side.

Conical and annular milling cutters, Fig. 29, are much employed for a great variety of work, such as the cutting of rymers, the making of milling cutters themselves, beveling, cutting the serrated part of hand and thumb screws, etc. In Fig. 29, A, B, C, D are edge views of some of these cutters; K represents a face view, and E a section of one of them

Any complex forms, such as the spaces between the teeth of spur, miter, and other wheels, can be machined by using what are known as the patent cutters, which can be re-sharpened as often as required by simply grinding the face of each tooth. They are so constructed that however often they are reground they never lose their original curved forms, and always produce the same depths of cut. One of these cutters, for instance, will cut the same standard shapes of teeth in a spur wheel, after it has been used for years, as it did the first day it was started.

There is risk of fracture in making large milling cutters out of one solid cast steel blank, the principal difficulty being in the tempering. In practice it is found that if they are required of larger diameter than about 8 in. they are better made of wrought iron or mild steel disks, with hardened cast steel teeth, so securely fitted into them that they do not require to be removed. The cutting edges can then be re-sharpened in their own places, as in the case of the ordinary milling cutter; thus insuring that each shall have the same angle of cutting and clearance, run perfectly concentric, and therefore do a maximum amount of cutting in a given time. It must, however, be borne in mind that the smaller the diameter of the milling cutter the better finish it will produce; and cutters of large diameters should only be used to reach into depths where one of smaller diameter could not. Again, the smaller the cutter the less does it cost to make and maintain.

The writer has not had an opportunity of actually testing the relative amounts of engine power required for driving milling machines; but as far as he can judge from ordinary practice in doing ordinary work, he has not perceived that any more power is required to remove a given weight of shavings than that required for a lathe, planing machine, or shaping machine, with efficient cutting tools in all cases.

The cutting speed which can be employed in milling is much greater than that which can be used in any of the ordinary operations of turning in the lathe, or of planing, shaping, or slotting. A milling cutter, with a plentiful supply of oil, or soap and water, can be run at from 80 ft. to 100 ft. per minute when cutting wrought iron.

The same metal can only be turned in a lathe, with a tool-holder having a good cutter, at the rate of 30 ft. per minute, or at about one-third the speed in milling. Again, a milling cutter will cut cast steel at the rate of 25 ft. to 30 ft. per minute.

The increased cutting speed is due to the fact that a milling-cutter, having some thirty cutting points, has rarely more than three of these cutting at the same time. Each cutting point therefore is only in contact with the metal during one-tenth of each revolution. Thus, if we suppose it is cutting for one second, it is out of contact, and therefore cooling, for the succeeding ten seconds, before it has made a complete revolution and commences to cut again. On the other hand, a turning tool while cutting is constantly in contact with the metal; and there is no time for it to cool down and lose the heat imparted to it by the cutting. Hence, if the cutting speed exceeds 30 ft. per minute, so much heat will be produced that the temper will be withdrawn from the tool. The same difficulty to a great extent applies to the cutting tools in planing, shaping, and slotting machines. The speed of cutting is governed also by the thickness of the shaving, and by the hardness and tenacity of the metal which is being cut; for instance, in cutting mild steel, with a traverse of $\frac{3}{16}$ in. per revolution or stroke, with a shaving about $\frac{5}{8}$ in. thick, the speed of cutting must be reduced to about 8 ft. per minute. A good average cutting speed for wrought or cast iron is 20 ft. per minute, whether for the lathe, planing, shaping, or slotting machine.

THE CONCENTRATING MILL AT THE O'NEIL MINES, GALENA, KANSAS.

WE give a description and sketch of one of the numerous small and cheap concentrating works erected in the last few years in the lead and zinc region of Southwest Missouri and Southeastern Kansas, by the Fort Scott Foundry and Machine Works, of Fort Scott, Kansas. These works were constructed and erected under the superintendence of F. De Stwolinski, in charge of their mining department.

The concentrator herein described is situated at the O'Neil mines, formerly the Stanley mines, three miles from the town of Galena, Cherokee County, Kansas.

The ores, galena and zinc-blende, occur largely in pockets, with chert and lime-rock. The raw ore has an average of from five to six per cent. of galena, and from twenty to twenty-five per cent of zinc-blende.

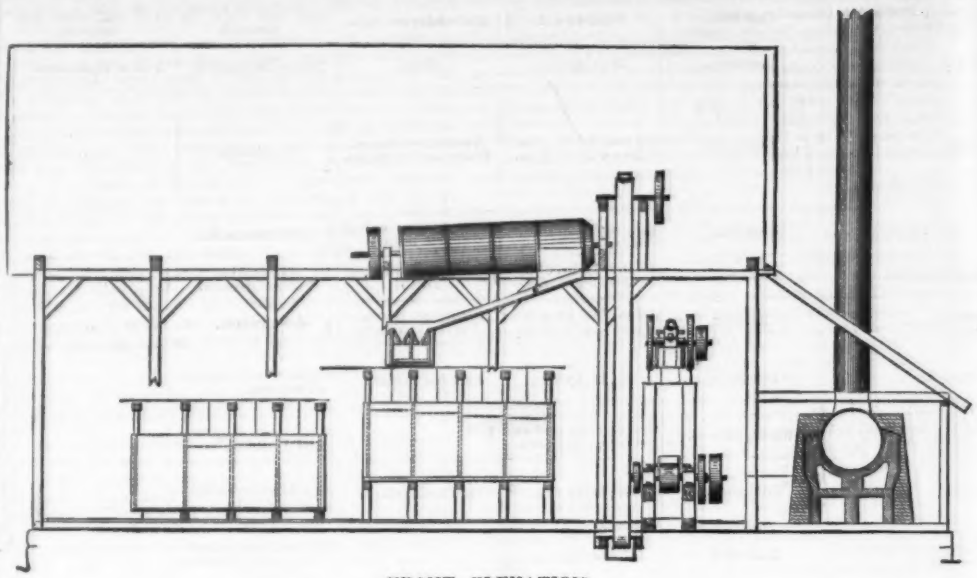
The building for the concentrator is 35 feet wide, 44 feet long, and 16 feet in scantling. The boiler and engine are in a small outbuilding, and are inclosed and covered by an extension of the roof of the main building.

The machinery consists of an improved Blake breaker, 7 by 10 inches opening, one set of crushing-rollers 20 inches in diameter and 14-inch face. The tires on the rollers are of very hard chilled iron, and so arranged on their cores that they can be easily replaced when worn out. The springs used are of rubber. The mill contains one elevator, with 12-inch belt: one revolving sizing-screen, having four sections, each 2½ feet long and 3 feet in diameter, made of Juniata sheet iron and perforated with holes 2 millimeters, 3¼ millimeters, 5 millimeters, and 7 millimeters; one hydraulic classifier, having two sections; and three double jig-machines, each having eight sieves, four on each side of the box, and forming two complete four-sieved jigs. The sieves on two of these double jig-machines, used for 2 millimeters, 3¼ millimeters, 5 millimeters, and 7¼ millimeters, are 18 inches by 32 inches. The sieves for treatment of fine stuff are 16 inches by 32 inches.

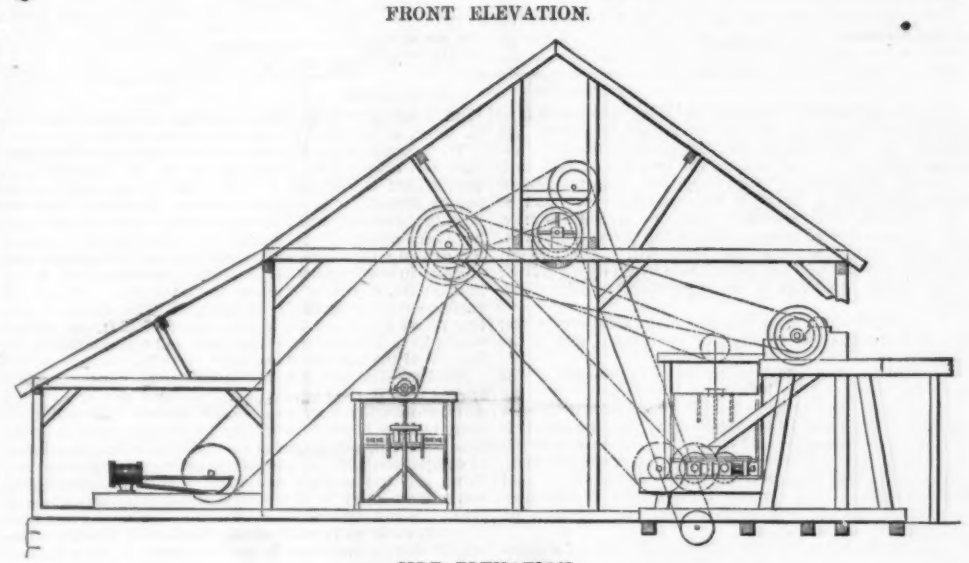
The sieve proper consists of a wooden net-shaped frame covered with No. 10 and No. 15 copper wire clothing. The jig machine for 2 millimeters, 3¼ millimeters, 5 millimeters, and 7¼ millimeters has side discharge (Rittinger) 4 inches square, and bridge regulated by a movable slide. The jigs for fine stuff, 1 and ½ millimeter, have bottom discharge. The jig machine for the coarser stuff furnishing the most mixed stuff for recrushing is placed so high that it can spout this stuff to the crushing rollers.

The motive power consists of a direct line, double balance crank, horizontal engine, with cylinders 11 inches in diameter and 12 inch stroke. A 35 horse-power boiler is provided to furnish steam for the engine, and a No. 5 Cameron pump lifting water from the creek to a tank near the concentrator, to supply the boiler and machinery with the necessary water.

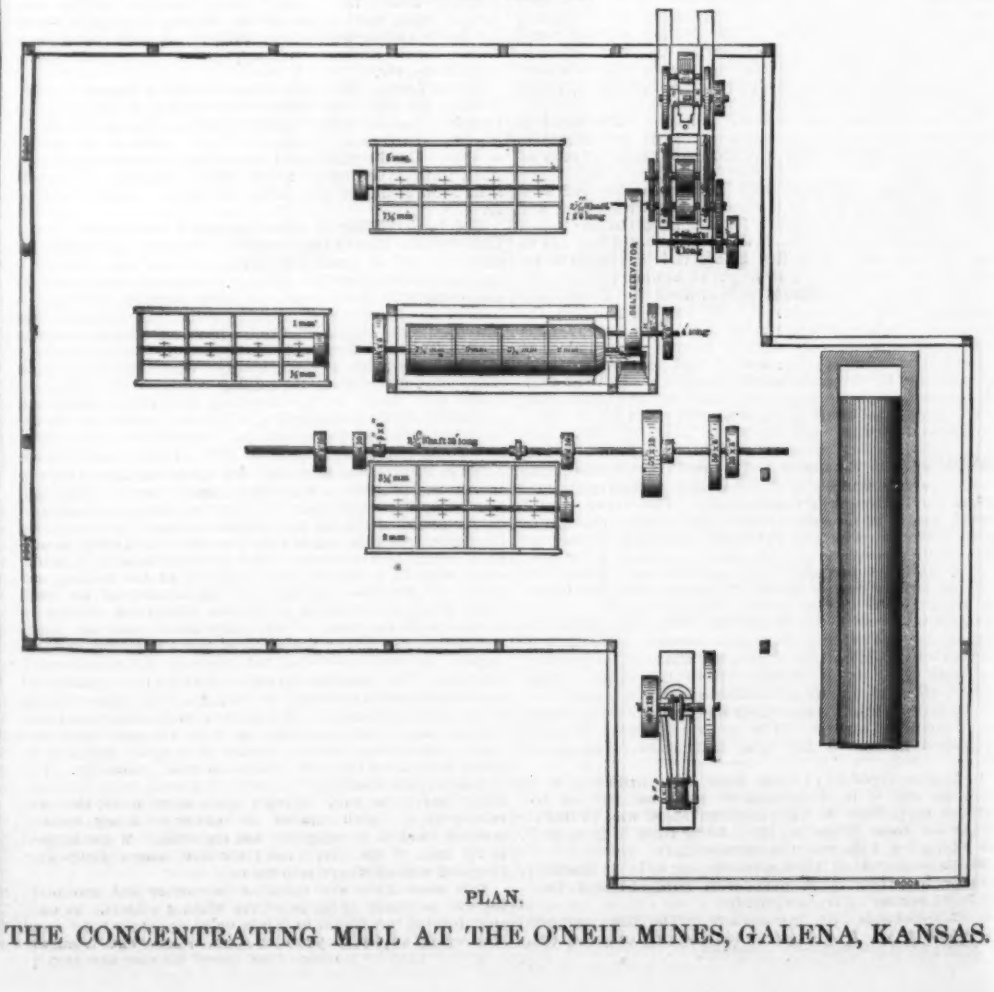
The raw ore is dumped on a platform in front of the Blake breaker, by which it is broken in pieces of one inch and less, spouted to the crushing rollers, and crushed sufficiently. From the crushing rollers it drops into the elevator, and is lifted to the revolving sizing-screen. The screen divides the crushed stuff into 2, 3¼, 5, and 7¼ millimeters. The stuff larger than 7¼ millimeters is returned by a spout to the crushing rollers, and the 2 millimeters and less is subdivided by the hydraulic classifier into three grades, 2, 1, ½ millimeters. The 5 and 7¼ millimeters is spouted from



FRONT ELEVATION.



SIDE ELEVATION.



PLAN.

THE CONCENTRATING MILL AT THE O'NEIL MINES, GALENA, KANSAS.

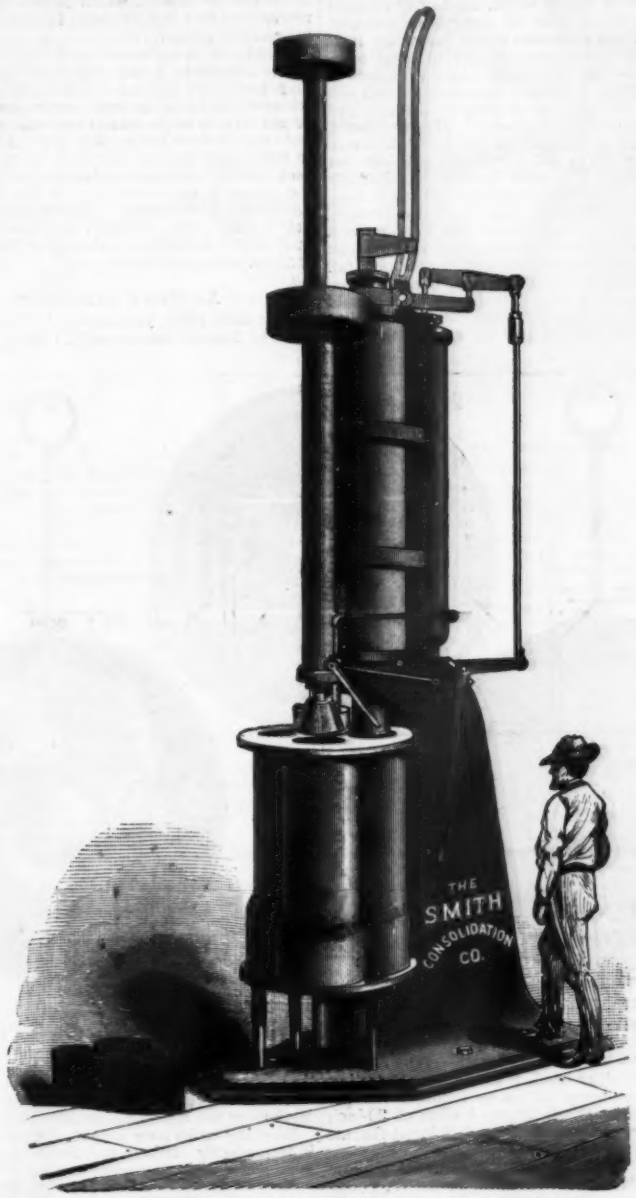
the screen to the double jig machine near the crushing rollers; the 2 and 3¼ millimeters to the one opposite; and the fine stuff, 1 and ¼ millimeter, to the jig on the end of the building. Each of these six sizes has for its separation four sieves, having a jigging surface of 16 square feet.

The first sieve of the jig machine discharges very clean galena; the second sieve, galena and zinc-blende mixed; the third sieve, clean zinc ore; the fourth sieve, zinc ore and rock; and the overflow is clean rock. The galena drops from the discharge into boxes, the clean zinc ore from both sides of the jig is spouted to small cars on the end of jigs; and the tailings are spouted to the outside of the building.

The capacity of these works is sixty-five tons per twenty-four hours. The force to run it is one hand feeding the Blake breaker, one hand attending to the jigs, and one hand for removing the clean product to the outside—a total of three hands for one shift. The cost of all the machinery complete, including engine and boiler, was only $5200.—*Eng. and Min. Jour.*

IMPROVED COMPRESSING MACHINE.

THE machine illustrated consists of a heavy steam-hammer operating upon the material contained in one of the group of three steel moulds. The moulds being passed through one-third of a revolution at each movement brings them under the hopper for filling, the steam hammer for



IMPROVED PRESSING MACHINE FOR BRAN, ETC.

consolidating, and the discharging hammer for discharging the mould of the block just formed, in such manner that the three operations occur simultaneously. One blow of the hammer, says the *Industrial World*, usually suffices to consolidate the block, which weighs from ten to thirty pounds, according to the material of which it is composed. Four blocks per minute can readily be made. The capacity of the machine represented is 3,000 pounds of fuel per hour from white pine sawdust.

The process, as applied to the majority of the substances named, consists in heating the material sufficiently to soften the inherent resin, gluten, or bitumen, and, while in this state, subjecting it to the operation of the consolidator. No foreign substance is in any case admixed.

To meet the ordinary requirements of the mills for a machine to compress bran or other offal into packages of such density as to make a freight equal to or better than sack flour, and which will leave the material in its natural condition when removed from the package, the process is modified by the omission of heating the material, and it is spouted directly from the mill to the mould, where it is subjected to the same operation for consolidation, forming a block which has sufficient cohesion, with the assistance of the package into which it is discharged, to retain its density and shape, but which resumes its natural bulk and condition upon being released from the package.

The importance of this invention to the milling interests of the country will be apparent when the results obtained with bran and mill offals are considered.

Bran has always been an article of forced sale, because of its bulky nature, being both expensive to store and unprofitable for export or shipment to points distant from the milling centers; whereas bran can now be reduced to one-fifth its natural bulk, rendering it at once a practical and valuable commercial article which freights better than sack flour, as the latter measures about 47 cubic feet to the gross ton, while the consolidated bran measures but 86 cubic feet to the gross ton.

Consolidated bran has proved to be of twofold advantage, since, air and moisture being excluded, it is not liable to damage by climatic effects, and blocks of bran made by this process over two years still remain as sweet and good as when made. This result alone is of immense value, for the reason that bran and other mill products may now be shipped to warm climates or may be kept in store for military campaign purposes for an indefinite time, which is not the case with these materials in their natural condition.

Sawdust, shavings, wood waste, coal dust, screenings, and cotton seed hulls for fuel are consolidated into self coherent blocks by the same means and in the same manner as heretofore described; and something of the industrial revolution about to be created by this method of disposing of the waste products of the saw mills may be appreciated, when it is considered that they represent fully one-third of the log measurement, amounting annually to millions of tons of now more than useless material, much of which can be manufactured into fuel having an ascertained value of $3.25 per ton in Chicago. This is done at a total expense of 70 cents per ton for the consolidated blocks on board vessel or cars at place of manufacture.

The value of these blocks as fuel, in comparison with Illinois steam coal, has been found to be such as to induce several large consumers to place standing offers for quantities at the price above named. The blocks possess the further merits of cleanliness, burning almost smokeless and ashless, and entirely clinkerless. For domestic purposes they are especially desirable, as they can be made of any shape or size.

The aggregate possible value of fuel from this source alone defies calculation, and still, in place of being a burden to the manufacturer, it disposes of a nuisance and source of danger about the saw mills, and the expense incident to the construction and operation of costly furnaces or burners with conveyers, etc., for consuming these heretofore valueless products.

This applies with equal force to planing mills, where the presence of an accumulation of shavings is especially hazardous; and it is estimated that the output of the large planing mills of this city during the busy season yields as high at 200 tons of shavings per day.

Cotton seed hulls and much of the straw and grasses abundant in many sections of the West are by the same means reduced to a fuel equaling in value coal or wood.

A superior article of stone of great density and beauty can be produced by machine from any of the elements com-

COMPARATIVE TABLE SHOWING THE REDUCTION OF VARIOUS MATERIALS BY CONSOLIDATION.

	Bulk unconsolidated per ton of 2240 lb. Cubic feet.	Bulk consolidated per ton of 2240 lb. Cubic feet.	Bulk unconsolidated per ton of 2000 lb. Cubic feet.	Bulk consolidated per ton of 2000 lb. Cubic feet.	Wt. unconsolidated per cubic foot. Lb.	Wt. consolidated per cubic foot. Lb.
Bran	172	35	153	31	13	64
Middlings	168	35	150	31	13	64
Ground Feed	168	35	150	31	13	64
Corn Meal	84	35	75	31	26	64
White Pine Sawdust	448	35	400	31	5	64
White Pine Shavings	336	35	300	31	6⅔	64
Yellow Pine Sawdust	224	35	200	31	10	64
Yellow Pine Shavings	168	35	150	31	13	64
Tan Bark	140	35	125	31	16	64
Cotton compressed	35	...	31	...	64	...
Hay, Straw & Grasses in mow	560	560	500	500	4	4
Hay, in common bale	160	160	143	143	14	14
Bituminous Coal Dust	44	40	40	36	51	56

posing natural stone. The stone made by this process weighs from 150 to 160 pounds per cubic foot, or 10 or 15 pounds more per cubic foot than Ohio sandstone.

The possibilities shown with the few substances before named apply in a greater or less degree to an indefinite number of articles. We have instanced enough concerning the products of this process to excite general interest in the particular mechanical devices by which they are secured.

The Smith Consolidation Co.'s office is at 254 South Water Street, Chicago.

THE JOINTING AND TESTING OF GAS MAINS.*

By C. W. FOLKARD, Assoc. Royal School of Mines.

THE conveyance of fluids through closed pipes under pressure has effected quite a revolution in one of the most important concerns of daily life—viz., water supply—enabling engineers to dispense with the cumbrous and costly aqueducts employed by the ancients; thus reducing the outlay to such an extent as to render the system applicable even to villages. For this purpose sound mains are necessary; otherwise the loss by leakage is a bar to the financial success of the undertakings. Fortunately, however, a serious leak in a water main soon makes itself visible, except under special conditions of soil; but in gas mains this is not the case to anything like the same extent. Sound mains are therefore of the utmost importance to gas companies; and in the present paper it is proposed to examine somewhat in detail the methods of jointing and testing now in use. This is all the more necessary at the present time in consequence of the tendency toward centralization of manufacturing stations; otherwise the leakage from the great length of trunk main necessary for the supply of outlying districts more than counterbalances the increased economy of manufacture in large works.

A theoretically perfect main would be one formed in lengths, like lead or composition pipe, by expelling molten lead or alloy through a mandrel. Each length would be jointed to the next by a stuffing-box or other contrivance, to allow of expansion and contraction. Practically, however, the great majority of mains (both water and gas) are of iron jointed with lead; so we will first consider the effect of changes of temperature on the ordinary lead joint.

It is well known by waterworks engineers that leaks regularly occur in certain parts of their districts in the spring and autumn; and if we examine these parts, we shall find that the soil is clay, and so the water finds its way to the surface, and attention is directed to the leak. But it is quite obvious that the same causes are at work all over the country; the difference being that when the soil is porous the water finds its way underground and unnoticed. This view is fully borne out by the fact, that in London, when anything is required to be done in the sewers, a time is always chosen when the service pipes are not charged. Exactly the same thing occurs with gas mains, but unfortunately the effects are seldom apparent until the main is examined; for, owing to the porosity and deodorizing power of the soil, the gas escaping into the atmosphere is composed of the inodorous compounds—marsh gas, hydrogen, and carbonic oxide. Every one who has taken up a main which has been buried for some years, even when originally well laid, must have been struck with the great number of joints either actually leaking or which have been leaking, as evidenced by the color and smell of the soil around them.

When we examine the theory of the matter, we shall see that it cannot be otherwise. Let us take a 4-inch pipe; the outside of the spigot being 4¾ inches in diameter, the inside of the socket 5½ inches in diameter; the joint being ¾ inch thick. When run with lead and set up, we have a ring of lead ¾ inch thick between two rings of cast iron. When first made it is absolutely gas-tight; but inasmuch as the coefficients of expansion of the two metals differ considerably, changes of temperature are fatal to its soundness. As to the limits of the range of temperature in the ground at about two feet deep, it is well known that in severe winters water mains are frozen solid; we may therefore fairly assume that the temperature of the ground falls to 30° Fahr. in winter, and if we take 60° Fahr. as the maximum in summer, we have a range of 30° Fahr. Iron expands $\frac{1}{1720}$ of its length, and lead $\frac{1}{1145}$ (more than twice as much) for this range; and consequently when the temperature has risen 30° Fahr. the ¾ inch lead ring, instead of being 0·375 inch, tends to become 0·37518 inch. The socket, by the same rise of temperature—viz., 30° Fahr.—becomes 5·5011 inches, and the spigot 4·7509 inches, the space between—viz., 0·7502 ÷ 2 = 0·3751 for the lead ring. This, however, as we have just seen, has expanded (or would have done if free to do so) to 0·37518 inch; consequently the yielding lead is squeezed out of the joint, which will probably remain tight. But when the action is reversed—viz., by a fall of temperature—it is evident that a space is left between the lead and the socket 0·00008 inch wide, through which gas or water can pass.

It is a well-known fact that large joints, *i. e.*, those in which the interval between the socket and spigot is (say) ¾ instead of ¾-inch—always give a great deal of trouble from leakage, the amount of which is far more than doubled

* Lately read before the Gas Institute, Sheffield.

when the size of the joint is doubled, and the experiments of Poiseuille on the flow of liquids and gases through capillary tubes afford an explanation of this fact. The minute space between the lead joint and the socket caused by change of temperature may be looked upon as a capillary tube 2 or 2½ inches long, and Poiseuille found that in capillary tubes of this length, the flow of gas was proportional to the fourth power of the diameters. Consequently, if this view is correct, the leak caused by variation of temperature in a ¾-inch joint would be four times as great as in a ⅜-inch joint, instead of simple double. This, at all events, shows the desirability of putting the large spigots in the large sockets, and not laying the pipes haphazard. Another fruitful cause of leaks is the absence of any provision for the longitudinal expansion and contraction of the main. In subways and other situations where the changes of temperature are great, expansion joints have been found to be indispensable, but this has not been considered necessary underground; consequently the lead joints in old mains are frequently forced outward, and a leak is the result. These unsatisfactory results are a consequence of systematic defiance of physical laws.

At first sight it would seem to be a very easy matter to devise a permanently gas-tight joint; but, unfortunately, this is by no means the case—indeed, I believe there are few more difficult problems. In the first place, it is evident from the foregoing considerations that the use of two metals is inadmissible, owing to their different coefficients of expansion; consequently we are limited to elastic substances like India-rubber or to rust joints for iron mains and soldered or screwed joints for very small mains and services. With regard to India-rubber, it is generally considered that the benzole vapor in the gas would act upon the joint and produce leakage. This, however, is not the case with the vulcanized material; and this form of joint has the advantage of allowing for both longitudinal and transverse expansion and contraction. There is an account of the practical application of the substance as a jointing material for mains in "King's Treatise on Gas Coal" (vol. ii., p. 358); but the results are so extraordinary as to lead to the conclusion that either the station meter must have registered incorrectly, or some mistake has been made in the calculations.

In the case of iron cement there would be no difficulty with regard to the transverse expansion, the material of the pipe and joint being similar; but stuffing boxes would be required at intervals, to allow of longitudinal motion caused by change of temperature. These might be inclosed in small brick pits to allow of tightening up and repacking periodically; but as the motion would be very slight it is probable that if made with asbestos or similar durable material the stuffing boxes would not require attention for many years, and so the brickwork would be unnecessary. To give notice of leakage, a ¾-inch pipe might be brought up to the surface fitted with a cap like a siphon-pipe, and examined periodically. By the use of lead service-pipes laid in wooden troughing it would be possible, in the majority of cases, to dispense with all joints between the main and the main cock in the consumer's house.

The foregoing remarks are merely intended as suggestions. The subject (simple at it seems) is a most difficult one, and requires much careful thought, which its great importance fully justifies.

The disturbance of gas mains by the subsequent operations of contractors for drains, sewers, water mains, etc., is a very important subject, and one on which, in my opinion, legislation is necessary. It is not at all unusual to find small mains broken across by the subsidence of trenches opened for these purposes; but the escape of gas in such cases is so great that attention is soon drawn to the spot. When, however, the result of the subsidence is merely to disturb or partially draw the joints, the leaks may go on for years, and the total loss to the company is probably far greater than when the main is actually broken. The average loss by leakage per joint per diem is about 1 cubic foot; and, judging from the great number of joints which on examination afford evidence of leakage at one time or another, I am of opinion that the bulk of the unaccounted-for gas is lost in such minute leaks as would take place by changes of temperature acting on the iron and lead. It would, I think, be very desirable to pass a law rendering it compulsory (under substantial penalties) upon contractors and others opening public roads to give notice to the local authorities of any main laid bare by their operations. The local board would then communicate with the gas or water company, as the case might be, and a check would be kept upon the way in which the work was done. It might even be specified in what way the main should be protected against subsidence, especially in cases where the line of drain or sewer, etc., made a less angle than (say) 10 degrees with the line of main. Such a law would only be affording a fair protection to companies. At present legislation is entirely on the other side.

Of course such modifications of the existing practice of main-laying would involve additional outlay; but the value of the gas saved by reduced leakage, when capitalized, would be found to represent a very large sum, which would be available for employing more perfect methods of jointing, allowing for expansion and contraction by changes of temperature, etc. Another invention or series of inventions may at any time make the cost of electric lighting equal to or less than that of gas. In such a case the adoption of the one or the other will be simply a matter of convenience and comfort; and few people who have been subjected to the discomfort and annoyance caused by leaky mains or services will hesitate which system of illumination to adopt. This, I venture to think, is another proof of the importance of this question.

We now come to the second division of the subject—viz., the testing of gas mains. This is a far more delicate operation than in the case of water, and unless proper precaution be taken it is very easy to condemn a tight main or pass a leaky one. These remarks apply only to the testing of dead mains (usually of large diameter) with compressed air; small mains being generally tested by filling them with gas and applying a light to each joint. When laid, the main is, of course, full of air at a pressure equal to a column of water 34 feet high or thereabouts. If we pump air into the main till the water gauge shows 18 inches pressure, it is evident that the absolute pressure in the main is 34 feet + 18 inches = 426 inches; and, by Boyle's or Mariotte's law, if the pressure in the main falls by leakage one inch, we know that $\frac{1}{426}$ part of the total air in the main has leaked away. Knowing the diameter and length, we can thus easily calculate the leakage in cubic feet per hour for a given fall of the gauge.

The following table shows at a glance the amount of leakage in cubic feet per hour corresponding to a fall of one inch per hour—viz., from 18 to 17 inches for 100 yards of main of various diameters:

Diameter of Main, Inches.	Area in Square Feet.	Capacity of 100 Yards in Cubic Feet.	Leak in Cubic Feet corresponding to 1 Inch Fall in the Gauge.
4	0·0872	26·16	0·061
6	0·1963	58·90	0·138
9	0·4418	132·54	0·311
12	0·7854	235·62	0·553
18	1·7672	530·16	1·24
24	3·1416	942·48	2·21
30	4·909	1472·70	3·46
36	7·068	2120·60	4·98
48	12·566	3769·90	8·25

If the main is 200 yards long, the leak indicated by one inch fall of the gauge is twice as great. When we have (say) 5 miles of 30-inch main to test, one inch fall on the gauge represents a loss of 304·4 cubic feet, and consequently $\frac{1}{24}$ inch fall in an hour represents 30 cubic feet loss per hour, or 720 cubic feet per diem. It is evident, therefore, that at least one hour's duration of test is necessary; and this being so, we must now examine the effects of changes in atmospheric temperature and pressure.

It is generally impossible to test an exposed main satisfactorily in this manner, owing to the rapid changes of temperature; but when the trench is filled in, or even if the main is just covered with soil or water, the hourly changes of atmospheric temperature have no perceptible influence on the gauge. With the variations of the barometer it is otherwise; and to test a large main properly a good barometer (preferably an aneroid) is essential, since variations in the height of the mercurial column to the extent of 0·02 and 0·3 inch of mercury per hour are of daily occurrence, and occasionally the range is much greater. Mercury being about 13 times as heavy as water, bulk for bulk, the above figures correspond to a rise or fall of 0·26 and 0·39 inch per hour on the water-gauge. The main, in fact, acts similarly to a water barometer. When the atmospheric pressure rises, the water in the gauge attached to the main is depressed, and *vice versa*. Turning to the table, we find that one inch fall per hour in 100 yards of 30-inch main represents a leak of 3·46 cubic feet per hour, and consequently 0·26 inch fall in 5 miles of 30-inch main represents 79 cubic feet per hour. That is to say, 5 miles of perfectly tight 30-inch main would show a leak of 79 cubic feet per hour (1896 cubic feet per diem), owing to a rise of 0·02 inch per hour in the barometric column. On the other hand, if at the time of testing the atmospheric pressure happened to be falling at the rate of 0·02 inch of mercury per hour, the 5 miles of 30-inch main would apparently be tight, although leaking at the rate of 79 cubic feet per hour.

Before making the one-hour test it is essential to allow half or one hour to elapse after pumping in the air, unless this latter operation has extended over three or four hours. This interval is necessary to allow the air to find its normal temperature, as the act of compression is attended with the evolution of heat; and if a main be pumped up quickly to 18 inches pressure, it will generally be found to lose 0·2 or 0·3 inch in the first half hour or so, afterward remaining stationary, provided it be tight, and no change is taking place in the height of the barometer. Conversely, if a main be pumped up to 20 inches pressure, and then sufficient air is allowed to escape to reduce the pressure to 18 inches, the inclosed air will have been cooled by expansion, and the (comparatively) hot sides of the main will gradually raise the pressure to 18·2 inches. It is thus evident that a loss of 0·2 inch for the first half hour after pumping up might be undetected by testing immediately, and thus a leaky main be passed as sound.

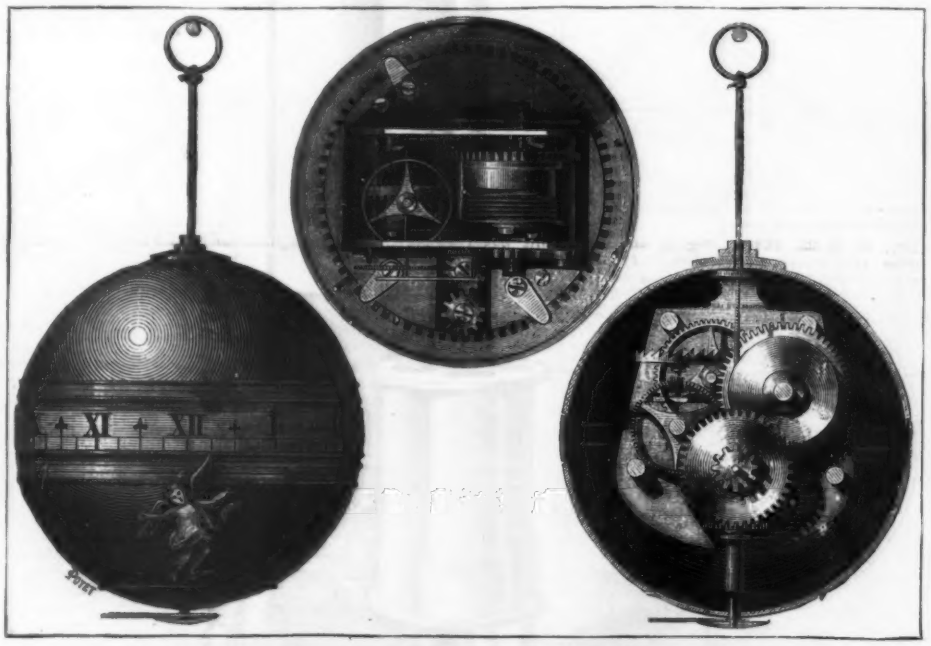
Minute leaks on the gauge are unimportant when testing long lengths of large main, since they rarely amount to 1 cubit foot per hour; and, as we have seen above, this in 5 miles of 30-inch main would be represented by about 0·3 inch on the gauge—quite an inappreciable amount. It is, however, far more satisfactory to have a tight gauge, and a piece of bent glass tube is by far the safest instrument. If the actual head of water be taken, not relying on a mark made on the gauge at the level of the water at the commencement of the test, it is immaterial if some of the water leaks away during the trial.

It is frequently asserted that wet weather is unfavorable for testing mains by compressed air, owing to the great condensation which takes place, whatever that may mean. My experience is in accordance with what theory would indicate—viz., that the dryness or dampness of the atmosphere is without the slightest effect on the results of the testing. Indeed, as wet weather is usually accompanied by a falling barometer, the reading of the gauge, when uncorrected for changes in atmospheric pressure, is generally favorable, and is often higher at the end of the test than it was at the beginning. Then, again, the porosity of the metal of which the pipes, and more especially the irregulars (bends, tees, siphons, etc.), are composed is said to be the cause of any leak which may be indicated. Now it is quite true that the bosses made by filling up the holes by which the core was supported are frequently unsound; and it is always advisable to put irregulars under pressure, and paint them over with soap and water, by which any leak is at once detected. But there is no such thing as general porosity. If a leak takes place, it is always at a part of the casting which is composed of drossy metal, or from some other defect equally apparent. Ordinary cast iron is practically impervious to gas or air. So also with regard to the magnitude of the leak or leaks. We may be quite sure that to have an appreciable effect on such a large bulk of air as is contained in several miles of (say) 30-inch main, the escape must be considerable, and no slight bubbles found by applying soap and water to the union or other parts of the testing gauge will be sufficient to cause even $\frac{1}{16}$ inch fall per hour (after correction by the aneroid). The joint at fault will be found to have possibly an eighth or a quarter inch hole, from which the air will be issuing with sufficient noise to be heard three or four yards off. This is my own experience, and is fully borne out by theory, which indicates that $\frac{1}{16}$ inch fall is represented by a leak of about 16 cubic feet per hour—a very appreciable amount.

Finally, with reference to the degree of soundness practically attainable, I can only state that 5 miles of 30-inch main have been laid, on which there was absolutely no leak whatever, so far as the most careful and prolonged tests (five or six hours) could show; and that which has been done once can be done again. The great thing is to be reasonable in one's expectations; and the only way is to calculate for each testing how many cubic feet per hour a certain fall of the gauge is equivalent to. If this be not done, it is perfectly easy to condemn a 4-inch main because it is losing half a cubic foot per hour, or to pass as sound a 48-inch main which is leaking at the rate of hundreds or even thousands of cubic feet hourly.

ANCIENT SPHERICAL CLOCK.

THE small clock represented in the annexed cut appears to be of interest because of its rarity. Up to the present time I have not been able to find it described in any works on clock making, either at the Conservatoire des Arts et Metiers, or the museums, or even among amateurs.



FRENCH SPERICAL CLOCK OF THE 17TH CENTURY.

Running by its own weight, and arranged for suspension, it is perfectly adapted for use on a pleasure boat or on a gondola, whence, perhaps, its name "Venetian Ball," notwithstanding its French make. Its construction dates back to the beginning of the seventeenth century. It consists of two hemispheres of gilded copper fixed to an internal ring, and having between them an empty space in which revolves freely a silver circle analogous to the one in revolving circle clocks. This circle carries, engraved upon its surface, the hours, as well as divisions corresponding to the quarters. The hour and its fractions are indicated by the extremity of the wing of an angel fixed in relief on the surface of the lower hemisphere, and which serves as an index or hand.

Beneath the lower hemisphere projects a rod which is in the axis of the ball, and which makes one revolution per hour, and carries a needle that presents itself in front of a dial divided into four parts that correspond to the quarters of an hour. This needle serves at the same time for setting the circle.

The wheelwork, which is mounted in a case between two pillar plates, consists of a fusee and a series of wheels and pinions, as usual, which terminate in a scape-wheel controlled by a verge escapement. With the wheels of this train gear those that revolve the circle and the rod placed in the axis of the ball. The cord which issues from the upper hemisphere, after traversing a tube that guides it, is fixed by one extremity to the cylinder of the fusee. The other extremity serves for suspending the ball. What is peculiar in the arrangement of the fusee is that, while acting as a barrel, it contains a spring which, in measure as the ball descends through its own weight, and the cord unrolls, winds up; so that, as soon as the ball is raised up, the spring reacts, causes the cylinder to revolve, and winds up the cord again. The winding is thus performed automatically, without the use of a key. The balance-wheel is of iron. The scape-wheel is large, as in all watches and clocks whose escapements were made before the discovery of the balance

spring, and in which the mass alone of the balance-wheel served as a regulator.

The spiral spring with which the balance-wheel of this clock is provided has certainly been added since the apparatus was constructed, judging from its arrangement and the aperture formed in the sphere for the passage of the rod that serves for regulation. This spring, however, is of a peculiar form, for it scarcely makes one turn before it terminates in a rectilinear piece 15 mm. long, which is held in a movable pinch plate serving to regulate it. The screw which moves this plate, and the rod of which projects externally, must have served for regulating the angular amplitudes of the balance-wheel before the latter had any spiral—a subterfuge employed in time-pieces of that epoch, and particularly in those in which a balance was substituted for a balance-wheel.

Unfortunately this clock bears no name to make me sure as to its origin.—*P. Garnier, in La Nature.*

ELASTIC WHEELED TRACTION ENGINE.

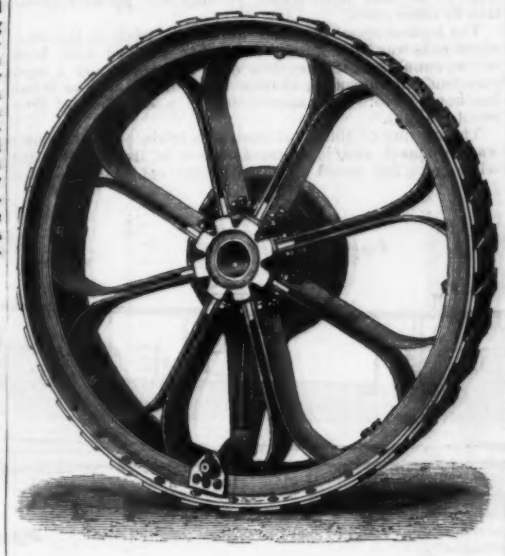
A GREAT many attempts have been made at various times to mount engines on springs, but these have always failed because it was difficult to make the motion of the spring accommodate itself to the action of gearing. But very successful spring-fitted chain gear engines were made as much as twenty-five years ago. The most promising scheme for spur-geared engines consists in putting the elastic medium into or on the wheel. The late Mr. Thomson did this with India-rubber tires, and Mr. Bridges Adams suggested putting a ring of India-rubber between the felloes of the wheel and the tire, and this plan was carried out in certain "steam sappers" by Messrs. Aveling and Porter; but India-rubber is very expensive, and the tendency which it always displays to creep round a wheel wears it out. In the engine which we illustrate below, Messrs. McLaren have made a new departure, and produced, in our opinion, the best solu-

Fig. 1

Fig. 2

tion we have met with of the entire difficulty. The engravings go far to explain themselves. It will be seen that the ordinary spokes are replaced by steel plates 8 in. wide by ⅛ in. thick. They are bent at the ends, and loosely secured to the inside of the tire by a clamp and two nuts and bolts. In an experimental wheel made on this system the spokes were in continuous pairs—that is, each loop, as we may call it, was in a single piece, as in Fig. 1, but they broke at the point, A, and to obviate this they are cut in two, as in the sketch, Fig. 2, and the result has been quite satisfactory. Several of these engines are at work, and one has run over 2,000 miles without the slightest evidence of wear. The springs are of crucible cast steel, specially rolled and bent for the purpose, and tempered in oil.

Recently we watched the performance of one of these engines—the property of Messrs. Bagge and Co. of Newbury—on a trip from Newbury to the new railway works at Tothill, on the line from Didcot to Southampton now being carried out by Messrs. Falkner and Tancred, contractors. The distance from Newbury to a skew bridge being built across the line is four miles, and the road is very hilly. The gross load taken—two wagon loads of bricks—was about 24 tons, but this is much less than the engine can take. The trip was made in one and a half hours, much delay being incurred in waiting for horses to pass and taking in water. No attempt was made to run more quickly than usual. The spring wheels, while not possessing too much elasticity, give great softness of movement. There is none of that jarring vibration—enough, as drivers say, "to shake one's teeth out"—experienced with the ordinary type of engine. A poker may be laid across the tender and will not be shaken off, and the engine is spared an immense number of strains and jars. Nothing can be more satisfactory than the performance of these wheels. It remains to be seen if they will be durable—that is to say, will the springs stand? Experience alone can settle this definitely, but we have no doubt on the point. The question is one for the steel maker, however. There is no undue strain put on the metal, and if the steel is of the right kind it will stand. If it is bad, it will crack. It must be understood that no twisting strains are brought on the spokes, for the motion is communicated to the wheel by a long arm keyed on the main shaft and pins. The dimensions of the engine are as follows: The steam-jacketed cylinder is 9 in. diameter by 12 in. stroke, and is fitted with a phosphor-bronze slide valve and piston rings; the piston rod, slide spindle, and other rods are of mild steel. All the working gear is of Yorkshire iron thoroughly case-hardened. The crank shaft is bent out of a bar 4 in. diameter, and turned down at the ends to 3⅜ in.; the second motion shaft is 4¼ in. diameter of mild steel; the main axle is 5⅜ in. diameter, also of steel; the gearing throughout is Hadfield's cast steel. The engine is fitted with two speeds for the road, viz., ratio of slow speed, 27·4 crank shaft revolutions to 1 of road wheels; ratio of fast speed, 12·4 revolutions to 1 of road wheels. The driving road wheels are 6 ft. 3 in. diameter by



16 in. wide, fitted with hard steel diagonal cross plates 3½ in. by ¾ in., with 2¾ in. spaces between the cross plates. The front wheels are 3 ft. 9 in. diameter by 10 in. wide, fitted with extra long chilled bushes. The axle ends are casehardened. The front end of the engine is carried on a front turning bracket fitted with two of Timmis' springs; the steering is done by worm and chain steerage worked from the foot-plate. The boiler has 152 square feet of heating surface, viz., fire-box, 38 square feet; tubes and front tube plate, 114 square feet; grate area, 6·6 square feet. The width of the engine over all is 7 ft. 7⅝ in.; length from center to center of front and back wheels, 9 ft. 11 in. The engine is fitted with a very powerful brake on the second motion shaft, a winding drum and steel rope for hauling heavy loads out of awkward places, and differential gear on the main axle for turning sharp corners, both pump and injector for boiler feeding, a water lifter for filling the tank, and a spring draw hook for pulling the wagons.—*The Engineer.*

RAREFIED AIR AS MOTIVE POWER.

COMPRESSED air having been utilized on a large scale as a source of power, or rather for the transmission of power, for large operations, it is now proposed to use rarefied air for small machines. The idea is to use it for purposes to which gas, water, and electricity have been used. Petit & Tatin, of Paris, propose to utilize it for subdivision and transmission of power for small industries, and have erected an experimental plant. It consists of an air pump in one building, a pipe 600 meters long, and motors placed in other places. The pressure in the pipes, which are 2½ inches in diameter, is about one-quarter of an atmosphere (7½ inches of mercury). They are connected with India-rubber, which is said to answer very well. The pipes are put in the sewers, so as to be easily accessible. The motors are single engines with oscillating cylinders. The socket forms a wind boiler, into which the air enters after exerting its expansive force in the cylinder. The machines work at three-eighths, and the smallest furnish a power equal to from 3 to 5 kilogrammeters (1/24 to 1/14 horse power). The velocity can be regulated by turning a cock through which air enters the cylinder, and the machine can be stopped by closing this cock. The machines run by this engine are small lathes for metal and wood, boring machines, meat choppers, sewing machines, etc.

This engine has the advantage, common to gas and water power, that it can be started or stopped at any time and requires no engineer, while it has this advantage over all other motors—that it acts as ventilator and takes the bad (and good ?) air out of the work room.

On the other hand, it cannot be economical, owing to the unavoidable loss. On account of the slight difference in pressure, the air pumps as well as the motors are disproportionately large.

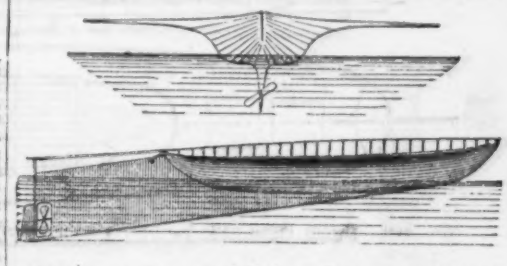
It remains to be seen whether the Parisian undertaking will be successful.—*Neueste Erfahrung.*

HIGH-SPEED BOATS.

A DOZEN years ago, says a writer in *La Nature*, I devoted much time to studying the conditions of locomotion in different media. I made sketches of numerous apparatus at that time; and, among my outlined projects, was a boat that had been inspired by the same theories as those that guided Mr. Pictet in his recent experiments, but differing from his in certain parts that special considerations caused me to establish. I was led in this direction through observing and analyzing the phenomenon of the ricochet, and through remarking the motions of little flat boats that were drawn along the surface of brooks by children on a run. My boat was to have had a flat bottom that was to be united to the sides by curves of very short radius. The keel, of slight thickness, and of slight width in front but becoming very wide behind and extending back of the boat, was to have carried at its extremity the screw and rudder. I had no delusions as to the difficulties in the way of a practical execution of my project.

1. Where could a motor be found of sufficient lightness, and yet powerful enough to communicate to and keep up in what I called my *ricochet ship* sufficient speed?

2. Supposing the apparatus worked in calm water, how would it behave on sea, between two waves? Evidently, in order to make its working possible, it would be necessary to make a sort of flying-fish of it. This is why I added to my project large horizontal planes above water that were to have aided in lifting, and at instants in sustaining the machine in the air. But how were such wings to be constructed,



and how were they to be folded up in case a tempest occurred?

I have often spoken of this project to intimate friends, and have jokingly said to them: "Follow with attention adepts in aerial navigation by means of bodies heavier than the air. When they shall have found a motor for traversing ten kilometers in their element without touching earth, I will use a like motor in the belly of a flying fish and will start for New York at the rate of 60 kilometers per hour."

No means, as well known, is at the disposal of man for crossing the ocean at the rate of more than 15 to 16 knots (say 20, so as not to offend Utopists), with the ships at present in use. Theory condemns floating bodies that cannot get through water at a rate not much exceeding 20 knots (less than 40 kilometers) per hour; but the science of the future may furnish us with a motor that shall convert into power the total amount of heat theoretically utilizable from the best fuels, and that too without being heavier than our present engines.

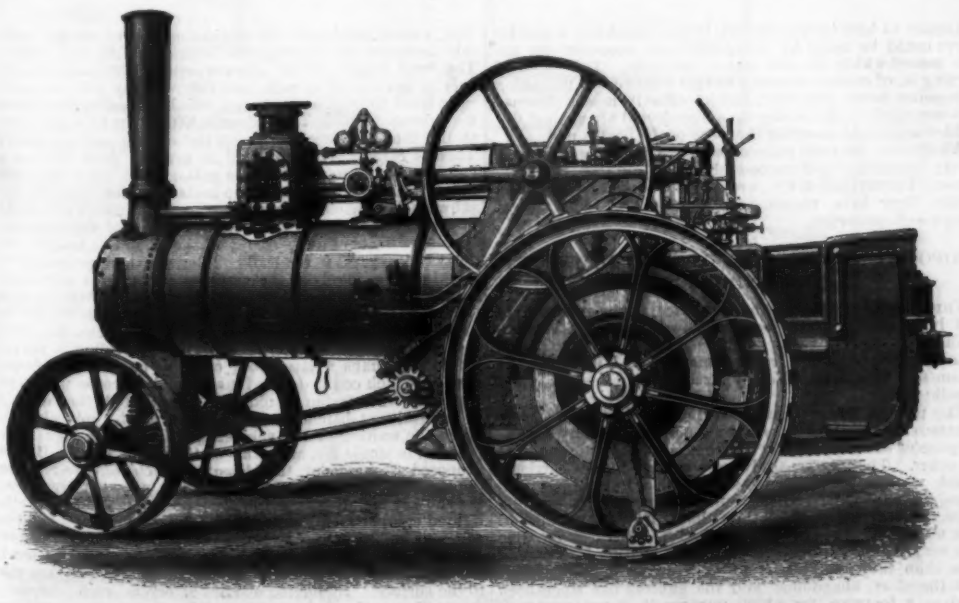
Economy in fuel has not yet to enter into a question of this nature, and such a consideration would be premature in the present state of things. Who would think of discussing the price and amount of consumption of the first apparatus that should render practical a thing of such importance as the one under consideration? Every one cannot build a very costly steamer in which the unforeseen is to play an enormous role, but it is within the power of every one to experiment on the behavior of analogous apparatus, with smaller models. Inventors should not lose sight of the fact that in an unexplored field every experimental instrument is quickly relegated to the waste heap by very reason of the teachings that have been extracted from it.

Why not get rid of the trouble of building a light steam engine by employing in the first place a reservoir of highly compressed air with superheater in case of expansion—the said reservoir being confounded in great part with the hull of the vessel? By actuating a motor by such a means, the considerable power stored up in advance under a slight weight might be expended as needed, in a very short time, sacrifice being made as regards the duration of the experiment until it should prove a success. Some practical data regarding such a motor are found in Admiral Bourgeois's submarine ship, which was built at Rochefort some twenty years ago, and which sailed alone for more than five hours by means of the compressed air in its storeroom. There exist at present self-moving torpedoes that are based on this principle.

There is a still simpler means: Uniform, sufficiently slow-burning rockets might be manufactured, and, after being experimented with to ascertain what thrust they exerted when burning, be attached in the proper direction to a model of a calculated size and weight.

Such a motor is applicable to certain apparatus that fly by means of inclined planes, in order to study their behavior and equilibrium, and it presents resources for the construction of interesting scientific playthings. If ever aerial locomotion is realized through a motor, it will doubtless be in rising from water into air, and mechanics, by a step analogous to that of nature, will pass from the fish to the flying-fish before getting to the bird.

To work then, and let us find an apparatus which shall be able to leap from the crest of one wave to that of another!



TRACTION ENGINE WITH ELASTIC WHEELS.

TWIN SCREW SHALLOW DRAUGHT STEAMER.

We illustrate the construction by Messrs. John I. Thornycroft & Co., of Chiswick, of a shallow draught steamer of exceptional design, intended for missionary service on the River Congo.

The boat, which is built of steel, is 70 feet long by 10 feet 6 inches beam at the water line, while her draught is but 19 inches. The engines and boiler occupy a place amidships, while forward and aft of this space good cabin accommodation is provided, the whole vessel from end to end being, moreover, covered by a light awning carried by suitable stanchions, and provision being made for hanging nettings from the awning to resist boarders in the event of any difficulty arising with the natives.

The boat is propelled by twin-screws, these being two-bladed, and 16 inches in diameter. On reference to Figs. 5 and 9, it will be seen that these screws are situated in tunnels or channels formed near the stern of the boat; the form of these channels, in longitudinal section, and the position of the propellers, being shown by Fig. 3, which is a section on the center line of the starboard engine. The propellers have their lower edges only 11 inches below the water line, so that under ordinary conditions the blades would be out of the water at each revolution. The effect of the tunnels is, however, such that the propellers have a full stream of water to act upon when the boat is running. At the same time a door in each tunnel directly above each propeller enables the latter to be readily cleared in the event of its becoming clogged by weeds, etc.

The propellers are of the guide-blade pattern, by Mr. John I. Thornycroft, and applied to H.M. torpedo boat Lightning. Each propeller is driven by a single non-condensing engine with a cylinder 6¼ inches in diameter with 8 inches stroke.

The boiler by which the engines are supplied with steam is a new pattern. It consists of a tubular ring situated at about the grate level, there being attached to this ring a large number of steel tubes one inch in external diameter, and these tubes being coiled spirally so as to form a dome-shaped firebox overlapped by an outer coil of similar form, the effect being that the products of combustion escaping through the central opening at the summit of the first dome-shaped coil are made to pass under the lower edge of the second dome-shaped coil before rising up to the chimney. The firegrate is very large, the boiler being intended for wood fuel.

From the upper edges of the two dome-shaped coils the various tubes composing them rise upward vertically, until at their upper ends they are curved inward to join the separator, which is a cylindrical vessel into which the tubes above mentioned enter laterally, the mixture of steam and water discharged from them striking against a cylindrical screen which is fixed within the upper part of the separator. The upper edge of the screen fits the separator closely, and thus the mixture of steam and water can only pass downward. In taking this course the mixture is acted upon by a series of spiral guide-blades formed on the exterior of the screen, these giving to the downward current a rapid circular motion, and thus causing the water to be separated from the steam by the action of centrifugal force. The water thus strikes against the side of the separator and falls to the bottom, while the steam turns inward under the edge of the screen and rises to the perforated upper end of the steam pipe shown.

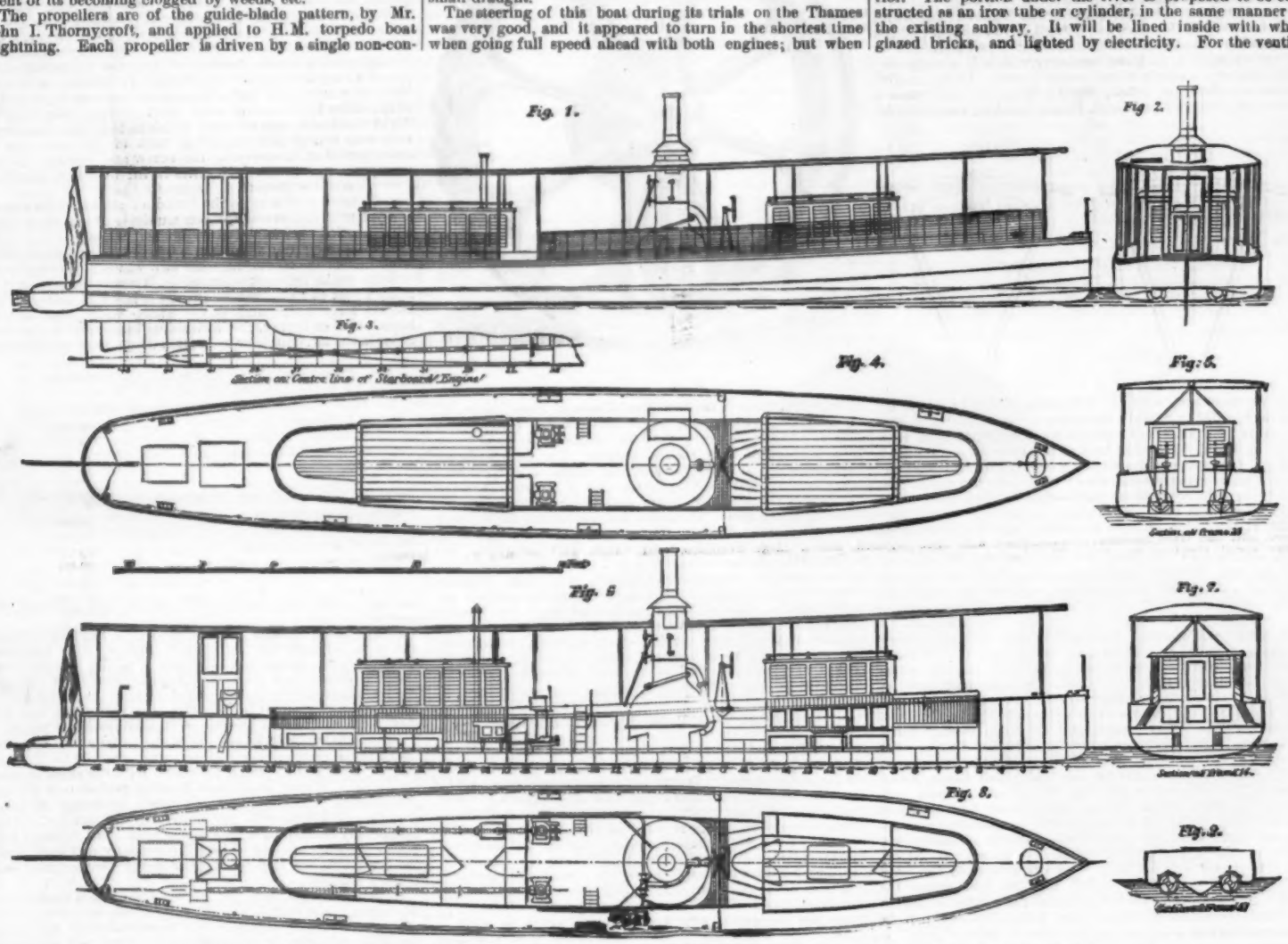
A large pipe extends from the bottom of the separator to the bottom ring from which all the one inch pipes forming the coils spring, this large pipe completing the circuit and returning the unevaporated water to the bottoms of the coils. Owing to the coils being filled with a mixture of steam and water much lighter than water itself, while the large return pipe is outside the casing of the boiler and hence not exposed to heat, the circulation through the coils is exceedingly energetic, while the separator answers its purpose admirably, the boiler yielding good dry steam. The feed water is delivered into the bottom ring.

Of course, this boiler having an exceedingly small water contents in proportion to the heating surface, generates steam very rapidly, the getting up of steam from cold water being but the work of a few minutes. As such a boiler would be liable to very sudden augmentation of pressure in the event of the engines being stopped at a time when a fierce fire was in the grate, an exceptional amount of safety valve discharge area has been provided. This has been obtained by simply making the top of the separator one large safety valve held down by a central spring. The boiler is inclosed by a light sheet-iron casing, which takes apart for carriage, as do also the tubes forming the coils, so that the whole is admirably suited for transport. The excellent results which this boiler gave during the trials of the boat under notice promise well for its application in other cases.

The highest speed recorded during the trials on the measured mile was 10·49 knots, this being attained with both screws running at 480 revolutions. This result was a most excellent one for such a shallow boat, and we believe it has has never before been approached by a screw boat of such small draught.

The steering of this boat during its trials on the Thames was very good, and it appeared to turn in the shortest time when going full speed ahead with both engines; but when the space to turn in was limited, it was found that a smaller curve could be made by using only the propeller on the side *toward* which the turn was to be made. This mode of turning is, of course, contrary to that followed in managing twin-screw boats generally, but its effectiveness in this case was very marked, the strong stream projected aft against the rudder appearing to swing the stern of the boat round.

Altogether, the little steamer we have been describing is a very interesting and successful vessel, and her builders, Messrs. Thornycroft & Co., are to be congratulated on the results they have obtained with a boat of such novel design.—*Engineering*.



TWIN-SCREW SHALLOW DRAUGHT STEAMER FOR THE RIVER CONGO.

PROPOSED NEW TUNNEL UNDER THE THAMES, LONDON.

THIS scheme consists, in the first place, in the enlargement and improvement of the existing Tower subway for pedestrian traffic, and in the second place in the construction of a subway for vehicular traffic from Tower Hill under the Thames to Vine Street, Tooley Street, with accesses by hydraulic lifts.

The present Tower subway, authorized in 1868, was constructed at a very small cost by a private company for the purpose of carrying passengers from one side of the river to the other. The tube was only large enough for one carriage, which was propelled across, shuttle-wise, by stationary engines and wire rope. It was found, however, after working it in this way for a short time that it would not answer. The number of passengers that could be carried at one time was very limited, and people were kept waiting for a longer time than they would take to walk across. The carriage was therefore, abandoned, and the subway has since been used as a footway, for which purpose it is not very well adapted, being too small. The accesses by steep spiral stairways, moreover, are very inconvenient. In spite of these drawbacks, however, it has been used by an average of nearly a million persons annually since it was opened to the public. At any rate, it has proved the ground at this place, and shown the possibility of constructing a subway at this and similar positions with certainty and at moderate cost. It is now proposed to divert the northern end of this subway vertically so as to reduce very considerably the depth of the shaft. Also to improve the access at each end, providing commodious and easy stairways, and adding hydraulic lifts, and to enlarge the subway so as to give a footway twelve feet wide The subway is to be lined with white glazed bricks, in the manner adopted in the subway leading from the Houses of Parliament to the Westminster station. Moreover, it is to be efficiently lighted by electricity, and perfect ventilation is to be effected. In short, it is proposed to provide a cheerful walk, protected from the inclemencies of the weather, from one bank of the river to the other. As indicating the traffic which it would be possible to accommodate in a foot subway of this size, it may be stated that the eastern footway of London Bridge, with a recorded traffic of as much as 77,000 persons in one day on that footway, is only nine feet four inches wide, including the curb.

The proposed carriage subway is to have a minimum diameter of twenty-three feet six inches, which will admit of a roadway as wide as Lower Thames Street, and will be ample for the accommodation of two lines of vehicles, one in each direction, with a headway more than sufficient for the highest vehicles, and giving a lofty and open appearance to the interior. The portion under the river is proposed to be constructed as an iron tube or cylinder, in the same manner as the existing subway. It will be lined inside with white glazed bricks, and lighted by electricity. For the ventilation, a small portion of the mechanical power on the south side necessary for working the hydraulic lifts will suffice. The total length of the subway will be 450 yards, or just over a quarter of a mile, and the roadway will be practically level throughout. Access will be given to and from the subway by means of hydraulic lifts at the two ends, and at the foot of Tower Hill, near the eastern end of Lower Thames Street. It is proposed to arrange these lifts on a new plan, so as to admit of the passage of a continuous and uninterrupted flow of traffic in each direction through the subway. Hitherto the great objection to the use of hydraulic power in connection with a communication of this kind has been that the continuity of movement would be broken and delays occasioned to the traffic. The previous proposals of the kind have involved the employment of large platforms capable of receiving a considerable number of vehicles at a time. As a result of such an arrangement, there would be a stoppage of the traffic arriving after the descent, and until the return, of the platform. Then would follow a movement of perhaps a large body of traffic on to the platform, none of which could descend until all had come upon the platform. The traffic would thus pass through the subway in intermittent batches. This arrangement would also involve the waiting of the vehicles in the subway, and their passage, in single file, on to the platform for ascent. By the proposed arrangement, the plans for which we have had the opportunity of examining, each vehicle upon its arrival at the subway will at once, without stopping, drive into a well-lighted compartment, capable of taking the largest vehicle and four horses, and be at once lowered to the subway below and pass off and across to the other side, and again, without stopping, drive into a similar compartment, and be taken up to the surface. By having a series of several such compartments (the number being calculated for the maximum traffic) at each end and for each direction, conveniently disposed

for ingress and egress, to be used in succession by the vehicles on their arrival, a continuous passage of vehicles each way, without delays and without accumulation of traffic either upon the surface or in the subway, will be provided for. The working expenses of the lifts will in this way be also reduced to a minimum, for the power employed will always be in proportion to the number of vehicles passing through. During the hours of the day when there are but few vehicles passing only a proportionate number of the lifts will be used. In the case of the large lift, however small the number of vehicles—possibly for a single light cart—a platform capable of taking perhaps a score of vehicles, and consuming as much power as if it did, would have to be set in motion, and taken up and down.

Such, then, is a general outline of the latest proposition for affording the much needed accommodation for traffic below London Bridge, and which has our best wishes for its success. If carried out, as in the public interest we hope it will be, it will probably prove only the first of several which might be constructed at intervals to relieve the traffic and minister to the daily and hourly wants of a teeming population still further eastward. We should not omit reference to an important physical feature of the districts to be connected by the subway as favoring this mode of crossing. Between the north side and the south there is a difference of level to the extent of thirty feet. By employing hydraulic power these different levels will be united by a level roadway, and thus will be secured the advantage of a perfectly level bridge, where from physical and other circumstances it is impossible to have such a bridge.

The total estimated cost of the works, land, property, etc., is £275,000, and the time necessary to complete and open the subway about eighteen months. The engineer to the works is Mr. J. H. Greathead, M.Inst.C.E., and we understand that Sir William Armstrong & Co. will undertake the supply and erection of the hydraulic lifts and machinery.—*Iron.*

[AMERICAN AGRICULTURIST.]

A HOUSE COSTING $2,500.

WE present in illustrations 1, 2, 3, 4, and 5, plans of a house, containing ten good sized rooms, a large veranda—costing $2,500, and presenting a neat and attractive appearance. The building is of Queen Anne style, now becoming so very popular, and makes a very handsome and commodious residence for town or country. The general arrangement was suggested by a woman, who determined to dispense with the conventional main hall and stairway, occupying the most prominent place in the front part of the house, and provided, instead, a vestibule entrance outside the house, from a part of the veranda. This puts the stairs in a less conspicuous place, with approaches from two directions at the foot, thus making them serve equally well for general or family use from the main house, and as a private stairs from the rear extension.

Exterior (Figs. 1 and 2).—The outlines are angular, and somewhat picturesque. The body is two feet above ground, and but a few easy steps are required to reach the entrances from the outside. The extensive veranda and other projections afford protection from storms to the windows and entrances, besides affording desirable shade. The roofs are of dark slate, one-third of those on the main roof being pointed and laid in belts. A cresting of ornamental iron is set along the main ridges, and, when properly connected with ground rods, serves to protect the building from lightning. The window openings have a single light of plain glass in the lower sash, and several smaller tinted lights in the top one. The tinted glass, in a variety of colors, produces, with little cost, a very cheerful effect both outside and inside.

The cellar equals the first story in area. It has an outside entrance, five windows, and stairs leading to the first story. Height of ceiling, 6½ feet.

First story (Fig. 3).—The height of the ceilings is 10 feet. There are four good sized rooms, each with outlooks at their sides and ends. The main entrance is from the front veranda, through a good sized and pleasant vestibule, which is lighted at the side by a cluster window of tinted glass, and has side and end doors opening to the parlor and sitting room. The parlor has four windows facing three directions, each protected from storms, and agreeably shaded by the veranda. There is a large open fireplace, and doors communicating with the sitting and dining rooms. The sitting and dining rooms adjoin each other through sliding doors, which admit of their being used together, as occasion may require. The kitchen is convenient, well lighted, has a large fireplace, with range, and adjoins a pantry. The rear entrance, or porch, is also reached through a door from the sitting room. The stairs to the cellar and to the second story are placed between the dining room and kitchen, and may be reached from each direct.

Second story (Fig. 4).—Height of ceiling is 9 feet. This story has a central hall, three chambers, three closets, and a trunk room. The stairs to the attic are placed above those of the first story.

Attic (Fig. 5).—Height of ceiling is 8 feet at the plates or sides, and follows the rafters to the full height of 7 feet. A hall and three chambers are finished on this floor, with the doors and windows placed in the center of the ends of each.

Construction.—The foundations and chimneys are of hard brick, laid in good mortar. The frame is of sawed spruce; with siding, for the body, and clapboards laid on thicknessed sheathing and building felt. The gables and frieze courses are of redwood shingles, also on sheathing. The main roof is of dark slate, laid on sheathing and tarred felt. The veranda roofs are also of slate, laid on inverted pine flooring. The flooring outside is of 1⅛ by 4½ inch T and G pine; inside of 1⅛ by 7 inch T and G spruce. The windows have plank frames, with 1⅛ inch sash, glazed with second quality French glass. The doors are of seasoned pine, paneled and moulded. The inside finish is clear pine, reeded with blocks. The inside walls and ceilings are hard finished on two coats of brown mortar, and the principal rooms of the first story have neat stucco cornices. The painting is two-coat work, of selected colors.

ESTIMATE. COST OF MATERIALS AND LABOR.

160 yards excavation, @ 25 c. per yard	$40.00
15,000 brick, foundation and chimneys (complete), @ $15 per M.	225.00
32 feet bluestone, steps and sills, @ 30 c. per ft.	9.60
1,000 yards plastering, @ 30 c. per yard	300.000
210 stucco cornices, @ 20 c. per ft.	42.00
5,000 feet timber, @ $20 per M.	100.00
100 joists, @ 16 c. each	16.00
250 wall strips, @ 11 c. each	27.50
4,500 feet sheathing, @ 3 c. per ft.	135.00
450 clapboards, @ 16 c. each	72.00
21 bunches shingles, @ 1.50 per bunch	31.50
24⅛ squares slate, @ $9 per square	220.50
950 feet outside flooring, @ 5 c. per ft.	47.50
2,650 feet inside flooring, @ 4 c. per ft.	106.00
5 cellar windows, @ $3 each	15.00
23 full sized windows, @ $8 each	184.00
11 half windows, @ $5 each	55.00
29 doors, @ $7 each	203.00
3 stairs, @ $10 each	30.00
Veranda and porch finish	50.00
5 kegs nails, @ $4 each	20.00
4 closet finish	20.00
Mantels	30.00
Tin gutters and leaders	20.00
Carting	20.00
Painting	180.00
Carpenter's labor (not included above)	240.00
Pump, sink, and incidentals	60.00
Total, complete	$2,500.00

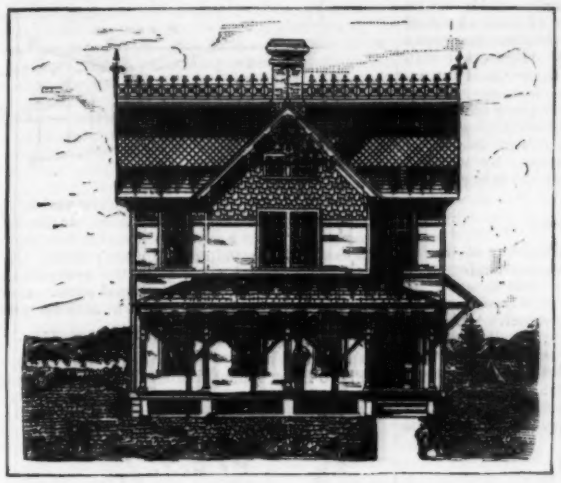


FIG. 1.—FRONT ELEVATION OF HOUSE COSTING $2,500.

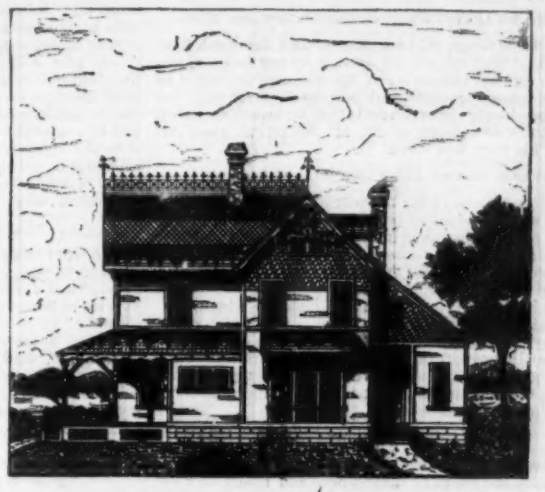


FIG. 2.—SIDE ELEVATION OF HOUSE COSTING $2,500.

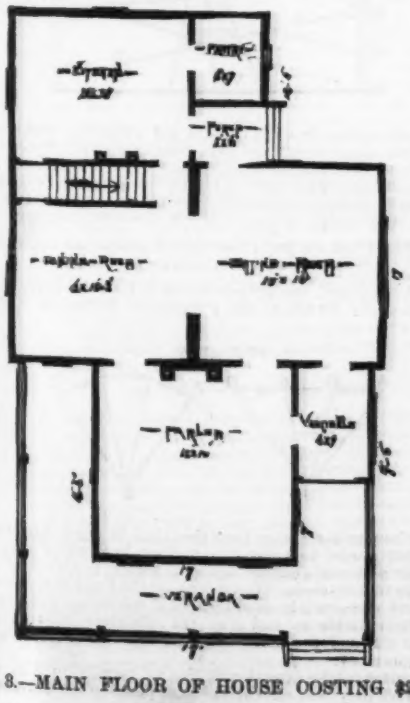


FIG. 3.—MAIN FLOOR OF HOUSE COSTING $2,500

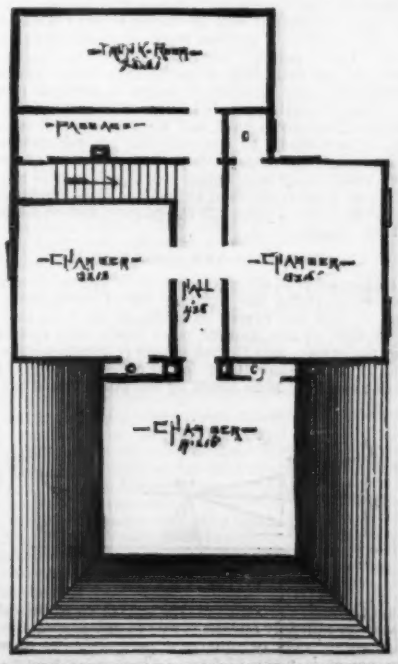


FIG. 4.—SECOND STORY OF HOUSE COSTING $2,500.

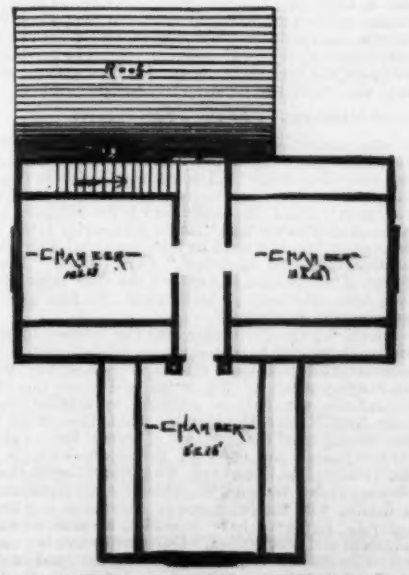


FIG. 5.—ATTIC OF HOUSE COSTING $2,500.

ATMOSPHERE AND SPACE IN PAINTING.*

By G. A. STOREY, A.R.A.

ART is full of problems—to some they appear mysteries—and there is a notion that an artist has but to stand before his canvas and call forth a picture into existence, as though he did it with a wand like a magician, or the good fairy in a pantomime; but this is not so. He has to work out his pictures and his problems, not by arithmetic, or algebra, or geometry, but by thought, and observation, and experience, and also by an additional power which I can only describe as feeling or love, which is a kind of sympathy in the artist for the beauty and the character of the objects and the scenes he represents. It is an enthusiasm for the observation of nature, which was carried to its extreme by the great painter Turner, who caused himself to be lashed to a mast for four hours that he might study a snow storm at sea. He did not

* A lecture read before the Society for the Encouragement of the Fine Arts, May 31, 1883.

expect to escape, he says, but felt bound to record what he had seen if he did, and he did record it.

THE ARTISTIC FACULTY.

This faculty, this love for the forms, for the colors, and the combinations that we see in nature, is essentially the artistic faculty, though not possessed in an equal degree by those who practice the art, but it is that which gives the stamp, the hall mark, the real value, to their respective productions. Many who do not practice the art have this faculty, and although they may not have the time or the power, or the opportunity to work out the problems of art and to produce works themselves, it nevertheless makes them lovers of art and true connoisseurs.

IMPORTANT TO ADVANCEMENT OF ART.

I address these observations, such as they are, to both sections—to those who look at pictures and appreciate them, as well as those who paint them; for it is of importance to the flourishing and advancing of art that not only the artists should know, but those also who care for art should understand as much as it is possible to teach of this delightful subject.

ADVANTAGE TO ARTIST WHEN OTHERS STUDY ART ALSO.

If the artist has to appeal to a careless and ignorant public, and to those who are willing enough to pay large prices for pictures, but not able to see if the pictures are really of value, then art must languish and become demoralized; but if, on the other hand, the artist feels that he has to deal with those who know something of his art, he is put upon his mettle to do his very best work.

ADVANTAGES TO THE ART PATRON TO STUDY ART.

It is therefore necessary for the patron and amateur of art to study the subject as far as he can, not only because it will increase the pleasure he takes in his own picture gallery perhaps a hundredfold, and protect him from folly and from fraud, but because also it will enable him to assist in the real advancement of art, and, at the same time, reveal to him and give him an interest in those beauties of nature which, perhaps, otherwise he might pass unnoticed. "We always appreciate," says Mr. C. R. Leslie, "and therefore enjoy a picture the more in proportion as we discover ourselves or are shown by others the why and the wherefore of its excellence, and much of the pleasure it gives us depends upon the intellectual employment it affords."

THE FIRST PROBLEM.

The first problem which we have to consider in painting is how to produce the effect of atmosphere and space on a flat surface, how to make that which is close to us appear distant from us, how to make objects which are on the same plane appear separated from one another and distant from each other, how to make a figure that is but a few inches high appear to be the size of life, how to make the spectator feel that he is looking, not at a flat piece of canvas with paint upon it, but into a mirror which reflects nature.

THE IMPRESSION MADE BY THE ART OF PAINTING.

Sir Edwin Landseer used to say that in looking at a figure in a picture he liked to feel that he could walk round it. And this exactly expresses the impression that the true art of painting should make upon the spectator, for it means that the artist has carefully and faithfully done his work.

It means that he has studied perspective, and drawing, and tone, and color, and light, and shade, and gradation, and atmosphere, and space.

PERSPECTIVE AS TAUGHT BY MATHEMATICIANS.

Perspective, as taught by mathematicians, is correct from one point of view only. The spectator must be exactly opposite the point of sight, and exactly so far from the picture as the point of distance, and, furthermore, he must be supposed to have only one eye. But this confines our drawing to too narrow a limit. Although by the aid of perspective we can draw objects bounded by flat surfaces (such as buildings) quite correctly, of what use is this mathematical science to us when we have to depict the wayward branch of a tree or a group of leaves, or waves heaving and dashing against rocks? and yet all these have their perspective. Of what use are our vanishing points when we have to draw the delicate rounding of a cheek or the curl of the lips, and how are we to give the perspective of a smile; and yet if you have to draw a laughing face that is partially turned aside, you have to consider the perspective.

THE ART OF PAINTING—THE ART OF PERSPECTIVE.

Now, the art of painting is the art of perspective, for it requires all the knowledge of the painter's art to produce the effect of atmosphere and space in a picture. You may study Kirby's treatise through and through; you may spend forty nights, as I did, under an eminent professor of perspective at the Academy; you may read the admirable French work of Mons. A. Cassagne; you may go back to Christiano Wolfio; or you may emulate the midnight studies of the painter Paolo Ucello, who nearly drove his wife mad, and I believe went quite mad himself, in working out problems in perspective, and still you will find that you cannot draw a single object that is at all irregular in form by its assistance.

THE TRUE PAINTER'S PERSPECTIVE.

The true painter's perspective is a very subtle kind of drawing, in which there is much more than we read of in treatises upon that subject. I do not say that these treatises should not be studied, for the science itself forms a firm basis to go upon. Mr. C. R. Leslie says in his valuable handbook for young painters that "linear perspective is the basis for linear grouping, and until its laws were well understood, composition remained imperfect." And again, "When a knowledge of perspective had settled the true principles of grouping with reference to background, we find extended composition well developed."

But we must go much further than the science of linear perspective if we wish to reproduce the subtleties of nature. We must adopt in painting a system of perspective which applies to every touch of the brush and every line of the pencil, and this can only be achieved by making careful drawings from Nature, thinking the whole time of the why and the wherefore of the direction of every line, and the tone of every shade and color of the objects we copy. In dealing with straight lines, and with the different sizes of objects near or far, we must be guided by our mathematics; but in dealing with the infinitude of curvatures and broken lines over the forms we have to depict, we must be guided by judgment and observation. Our perspective is a mental process wherein we conceive that we are modeling the forms of objects as we would in clay; that we are rounding and shaping our figures, albeit with the point of a pencil, and instead of drawing mere profiles and lines going to the right and left, we are forming or imagining that we are forming solid objects, and are making our lines and our touches come forward and go backward, giving them an emphasis and an expression in accordance with this imagining. This imparts a peculiar quality to a drawing by causing its every line to have a subtlety, an individuality, and a meaning which make it the result, not of a mechanical, but a mental process. It is attained by thought, not by rule and compass, and is beautiful in proportion to the ability, the feeling, and the taste of the artist. It will be well to remember these observations when you visit any museum or gallery where you see the original drawings of the great masters, as at the Louvre or the University Galleries at Oxford. You will, perhaps, find that some of those very undrawing-master-like looking things, those not always neat productions, possess a deep and extraordinary interest.

THE RULE OF THUMB.

Still we cannot set aside perspective; we must study, at all events, some of its laws, for we cannot affect to despise anything unless we know at least a little about it. Unfortunately, the manner of teaching it is generally so cumbersome and intricate that, instead of being, as Mr. Kirby calls it, "an entertaining study for any gentleman who shall choose so polite an amusement," it is so tiresome that many artists give it up in despair, contenting themselves with the good old rule of thumb, or handing it over to some patient drudge to do it for them. It is, however, a very simple and easy thing, and may be mastered in a few hours, and in a manner never to be forgotten, if we only set about it in the right way, and that is, reason it out, instead of learning it on the parrot or monkey system, by which I mean being shown how to do a thing, and not being taught the reason why it is so done.

THE PERSPECTIVE PONS ASINORUM.

The chief thing which we have to think about at the beginning of perspective is that, although we are dealing with geomotrical forms, and have to consider them as such, we nevertheless represent them in direct contradiction to the formulæ of plane geometry, or that geometry which we study on a ground plan. In geometry, parallel lines are equidistant, and can never meet. In perspective, if they are parallel, they must meet at some point on the horizontal line. A square or oblong figure which, in plane geometry, has its opposite sides equal and all its angles equal, as in Figs. 1 and 2, in perspective geometry has none of its

FIG. 1.

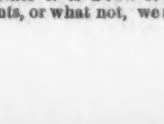
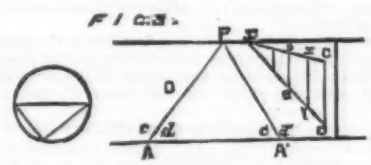


FIG. 2.

sides equal nor any of its angles, nor is its center X in the middle of the figure K L M N; but, although, according to measurements, these contradictions occur, we have to consider that this irregular figure K L M N, is really a parallelogram, that its opposite sides are equal, that all its angles are equal, and that the intersection of its two diagonals gives us the center of the figure.

This is our first difficulty. This is our *pons asinorum*, which, when once we have got over, all goes comparatively easy. But it is rather difficult at first to realize in a figure like No. 3 that a line, A P, which takes a diagonal direction

FIG. 3.



from the base line at A to the horizontal line at P, the point of sight, is really a perpendicular (seen on the ground plane) in perspective, and that angle C, which appears so much larger than angle *d*, is really equal to it, or that all the upright lines in this figure, DCX, are equal to each other, but they are so perspectively.

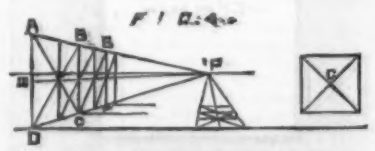
ATMOSPHERE AND SPACE.

M. Cassagne has framed a "Perspective Ladder," which is exceedingly useful; it will be found in his "Traite Pratique de Perspective," the best work on perspective that I know of. The "ladder" consists in this: any length may be taken on the first plane of the picture, either vertically or horizontally, and continued to the horizontal line by means of two vanishing parallel lines which start from the extremities of the given lines, and meet at a point taken at random, or according to convenience, on the horizontal line. The space between these parallels remains the same, however much they may appear to be reduced in the distance. These ladders are used to find the height and breadth of the various objects placed in the picture, and on whatever plane they may be.

DIAGONALS AND PARALLELS.

The employment of the diagonals of a square or oblong enormously simplifies the working out of perspective. If we want to find the center of a square, we draw two diagonals in that square, and the point where they cross each other is the center, and if that square is in perspective, we have but to do the same thing (as at A B C D, or E C F in Fig. 4) to obtain the same result by the assistance of the line

FIG. 4.

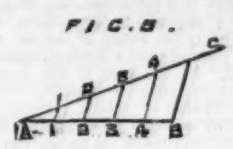


*x*P drawn through the center of the square to Ac vanishing point; we can multiply our diagonals to any amount, and so get as many oblongs or squares in perspective as we wish, and whether it is a row of trees, or houses, or columns, or pavements, or what not, we shall find them most serviceable.

THE PARALLELS

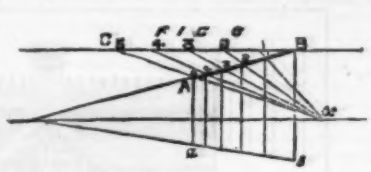
Are also ingenious and useful (Fig. 5). Suppose we have to divide line A B into a given number of equal parts, say 5. We draw line A c at random, and then measure off with

FIG. 5.



compasses on A C five equal parts; we then join C B and draw parallels to C B from all the divisions on A C, and these lines will divide A B into the same number of equal parts. Now let us do the same thing in perspective (Fig. 6). Suppose we wish to divide the perspective line A B into five equal parts: we draw B C horizontal to the base of the picture, and mark off with the compasses, as before, five equal parts on that line B C. We then draw a line C through A,

FIG. 6.

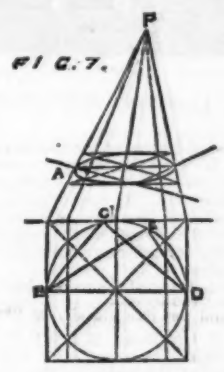


and prolong it until it cuts the horizontal line at *x*. From the points of division we draw lines 4*x*, 3*x*, 2*x*, and 1*x*, all going to the point *x* on the horizontal line, and therefore all perspectively parallel, and thus they divide the perspective line A B into equal parts, as in the previous figure they divide the geometrical line into equal parts. I need scarcely point out how very useful this is in architectural subjects.

KEY TO OBLIQUE PERSPECTIVE.

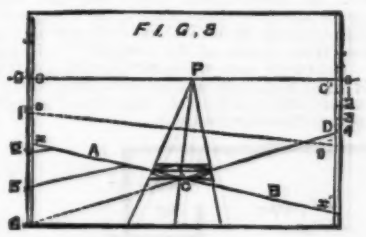
It is also difficult to realize at first that the oval figure A in Fig. 8 is the same thing as circle B, Fig. 7; but once you

FIG. 7.



have done so, and also have learnt that all triangles having the diameter of a circle for their base, and their apex at any point on the circumference, are right angle triangles, their right angles being on the circumference, as at C E, etc., and apply that geometrical problem to perspective, then you have the key to the whole of angular or oblique perspective, which is the only correct perspective; for it enables you, without any long vanishing lines, and indeed any of the cumbersome machinery of the old systems, to draw a line at right angles to any given perspective line in a picture; and the result is that you can thus easily get the main lines of

FIG. 8.

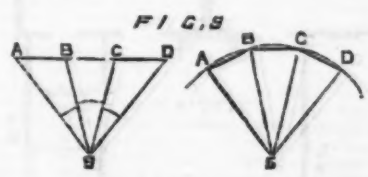


any perspective drawing. I am not aware that this useful problem of geometry has ever been applied to perspective. It is not only practically of great service, but this and the foregoing examples show us clearly that perspective is really geometry under certain optical conditions, and therefore, to study it properly, we must study it as we do geometry.

APPLICATION OF THE PERSPECTIVE CIRCLE TO OBLIQUE PERSPECTIVE (FIG. 9).

Having found the perpendicular C D to the perspective line A B, by means of the perspective circle, we wish to

FIG. 9.



know how to draw other lines that shall be parallel to them; in other words, to know how to draw lines which shall go to their points of distance without having to go out of the picture to find them. We prolong, in the first instance, line AB both ways until it cuts the edges of the picture at *x* and *x'*. We then divide *x o* and *x' o'*, the distances between the points *x x'* and the horizontal line, into two or more equal parts, as at *s s'*.

This gives us the direction of line *s s'* parallel to A B, and therefore they will meet at the same point on the horizontal

line. By subdividing these in the same manner, we can get any number of parallel lines. The same operation can be repeated with regard to C O; and by this means we can draw with ease the perspective of a wall ever so slightly oblique without troubling ourselves about a far distant vanishing point, which might have to be at the end of the garden. By this simple system, which is mathematically correct, we can carry on all the operations of perspective within the picture itself, which, I am sure, every artist will be grateful for.

ERRORS OF PARALLEL PERSPECTIVE.

It is a question whether what we call parallel perspective is really true; it is very easy, but it cannot be true mathematically, unless we draw our picture on a circular canvas like the canvas of a panorama, of which the spectator forms the center. In Fig. 9, if in the first one, S, the spectator, is looking at a straight line, A, divided into three equal parts, the angles of vision are not equal, for the center angle, B S C, is larger than those on each side of it; but in the second figure, where the straight line, A D, is bent at its divisions to form chords in a circle, all the visual angles are equal; but in parallel perspective we do not take this into account, and we draw a figure with one side exactly horizontal, and the other side vanishing. But this must be wrong; the only conditions under which we can see one side parallel to the base of the picture is when it is exactly in front of us, and when we cannot see the other side of it; but as soon as one side of a cube vanishes (that is, appears to decline from the parallel), then the other side must do so also in a proportionate degree. If we examine such a drawing carefully the wrongness is plainly seen. The further such a cube is removed from the spectator the larger it becomes. The side facing the spectator remains the same; but the side in perspective, the vanishing side, goes on increasing until at last it gets ever so much bigger than that facing you. I have pushed the cube to the extreme and beyond the limits of a picture, but if the principle is wrong there it is wrong everywhere else. It is a curious fact, that while professors of perspective have invariably allowed this error to pass, a true artist scarcely ever makes this mistake and photography can't. But we must leave this subject for the present. An artist is so far concerned about linear perspective, as it assists him in placing his figures and in drawing objects correctly; to sit down and work out endless problems in this science is, no doubt, a "polite amusement" and an intellectual exercise, but the painter requires to know only so much as will help him in his art and no more. He will find all he requires in M. Cassagne's book, where everything is clearly defined and illustrated. The landscape drawings are excellent as pictures, and there is scarcely any object, which comes within the range of artistic perspective, which is not explained—rows of trees, colonnades, arcades, cart-wheels, spiral staircases, chimney pots, cast shadows, reflections, etc., etc.*

COLOR.

In the coloring of a picture it is most important that we should continually remember that we are depicting atmosphere and space, as it will guide us in varying our tones and tints. One of the first essentials of good coloring is that each piece of it should be distinct, though ever so slightly different; the whole should be in harmony and beautifully graduated, and yet like mosaic, or like the separate pieces that are first carefully worked, and then sown together in the best tapestry.

To preserve the clearness of atmospheric effect we must not smudge about, nor put more touches on to our work than are absolutely necessary; for good painting is like beautiful language, it must express briefly, clearly, and forcibly our meaning. Each finishing touch in a picture should be considered like one word in a sentence. To put a number of touches where one ought to suffice is like stammering in painting; one of the greatest masters in this respect was Velasquez, but you will see much the same thing in many sketches by Vandyke, and if you look for this quality when you are at an exhibition of pictures, whether by old or modern painters, you will soon see which are the masters.

FAULT OF BEGINNERS.

One of the great faults with beginners is to make sharp, cutting outlines, and to bring light against dark too abruptly, and without any gradation, so that it is impossible for the eye to travel round the object depicted. Say it is a face against a dark background; it generally has a flat look, as though it were a piece of paper stuck on to a piece of black cloth; often the line of the hair is so cut out against the forehead that it looks more like a black cap than hair, and the same rigidity is carried through the picture. Nor is this peculiarity confined to young beginners only, but is characteristic of the infancy of art in all the different schools—even the great Albert Durer represents our first parents as though they were made of cast iron. This may arise from the fact that the first idea of delineation is to give an emphatic silhouette in profile of the form to be depicted, the idea of giving solidity, and the effect of atmosphere and space. The more artistic idea or a greater desire for truth of representation comes as the after-growth of experience. Leonardo da Vinci mentions as one of the tests by which you can tell whether a child has the artistic feeling or not, this desire for light or shade. He says, "Most children draw for their amusement but only make outlines, but the one who shades his outlines intuitively is the artist." Those who draw flat faces with black caps on instead of hair may be very fond of painting, but they are not artists, otherwise they would put light and gradation on the hair and round the features by proper shading, so as to harmonize them with the background, and make them appear to stand out from it, not stuck against it.

IMPORTANCE OF BACKGROUNDS.

And the background itself is of great importance. There must be light and shade, and gradations, in the background as well as on the figure, so that the light on the figure shall sometimes blend with the light on the background, sometimes come against a deep shadow to make it stand out, and sometimes against a half tone to make it retire again. There is much in backgrounds; they require more delicate finish than foregrounds, for the effect of atmosphere and space will give a tender look to even rugged rocks. They may be as rough, and rugged, and hard as you please in the foreground (unless washed to smoothness by the sea), but in the distance they must be delicate, and it is to be noted that a background that is scribbled in, and rough and careless, will destroy the finish of the most highly wrought figure, whereas a delicately graduated background will give the appearance of finish to even a rather roughly or slightly drawn figure.

*I cannot, however, commend M. Cassagne's perspective of the human head. It is, no doubt, quite right if the head is an egg, with little marks upon it for eyes, and nose, and mouth; but I shows how very inadequate is this science when we come to subtleties of art.

DISTANCE NOT TO BE OBTAINED BY FALSIFYING.

At the same time we must remember that distance is not to be obtained by falsifying. Many artists even now seek to give force to their figures by falsifying their backgrounds—that is, making them faint and feeble, under the notion that this will cause them to retire. It is not the case; the background, if falsely painted, that is, without its proper force and tone, instead of retiring like a real landscape, will look like a badly executed scene hung up behind the figures as on a stage. I have seen in even notable pictures (besides many others) interiors of rooms and galleries so painted as to receive no light from the windows represented at the back, which, instead of windows, appear like dull views painted on the wall. Look at this picture by De Hooghe, and you will see how true and faithful is really good art. While speaking of falsifying, I may as well point out another error which it is important to avoid, unless there is æsthetic reason for it, and that is magnifying unduly the size of a building or mountains, etc., in the distance; instead of increasing its grandeur by exaggerating its size, you simply bring it forward, and so diminish the distance, and with it the appearance of largeness.

And, again, another error is to try to put too much into a picture. You will see some picturesque views, so called, where the artist has tried to put all the mountains around him in one picture, so that instead of a few grand masses rising solemnly one behind the other, you have a number of little hills, that look more like so many waves dancing up and down; in fact, the mountains skip like rams, and the little hills like young sheep. On the other hand, it is wrong to make things too small. In Mr. C. R. Leslie's "Handbook for Young Painters," he says: "I have heard the diminutive proportions of the architecture in the cartoons defended, on the ground that Raphael's object was to give importance to his figures; but whether it was with this intention or not that he dwarfed his buildings, I have no hesitation in saying that it was not necessary to such an end that he should do so. The large architecture which forms the background to Titian's great picture in the Church of the Frari, at Venice, ennobles the composition, with no less of consequence to the figures, the dignity and importance of which is the first thing which impresses the mind; so that we see not even a Raphael may do a false thing."

BAD SYSTEM OF STUDY.

Before quitting this subject, I must say that the system of drawing which is encouraged at the Academy and other schools of art in England may have certain advantages, but it has great drawbacks, for, to begin with, it is false. The drawings in question, whether from the antique or from life, are generally well outlined and shaded with the greatest care; but there is no sign of any background. Instead of that, there is nothing but staring white paper, quite out of harmony with the strong finish of the drawing, which accordingly appears incomplete and cut out. Thus the young artist, at the very beginning of his career is, if not taught, at all events allowed to do a wrong thing which often clings to him through life. It is not only false, as we shall see, but is essentially inartistic, and to those who really are artists and have any feeling for color and effect, it must be almost as painful as it is a laborious task. The system of drawing on gray paper with black and white chalk, as adopted in the French ateliers and by the great masters, is right (note this beautiful little study by Sir David Wilkie), and is also easier and takes less time: two other great advantages, for the art student has so much to learn that he has no time to lose. Besides which, what sort of intellectual training can that be which condemns a student to sit week after week—nay, for months, perhaps years—before an antique cast, with a piece of chalk in one hand and a piece of bread in the other, going dot, dot, dot, like a sewing machine? A lady once wrote to me for advice about her son. She said she thought of making him an artist, because he was so weak in the head and was not strong enough to study; but I daresay he would have been quite equal to a stippled drawing.

HERCULANÆUM.—SPECIMEN IN PHOTOGRAPH.

Even a black ground is preferable to a white one, although that is not quite true; but it is highly decorative, as shown in the wall paintings found at Pompeii and Herculanæum. In these, the shadows melt into the dark ground, and the light portions tell out with the greatest amount of force. The eye is satisfied; and the result is, that the work impresses us with its unity and grace, and possesses that quality of repose and completeness which is so necessary to good art. But a figure highly shaded, with a white background, or rather no background, is at once destructive of this quality: the shaded side coming in sharp contact with white gives hardness, and not roundness. And what can be the value of the lights on the figure when they are opposed to such a mass of white all round it? The result is that the whole thing is cut up, and is as fidgeting to the eye as it is out of harmony both with truth and the artistic feeling; and although the subject may be one of the sublimest creations of the ancient Greek sculptor, both its grace and its beauty are lost, or at all events so interfered with, that we cannot contemplate this careful wrong drawing with any pleasure or even comfort. I have seen drawings, however, by students at the Slade School which are very much better in this respect, for they have indications of background, which is quite sufficient. If there is some cogent reason why all backgrounds should be white paper, then the drawing should be in harmony with it, and so slight that it is little more than an outline, as in those sketches we have referred to; or so delicately and tenderly worked that they harmonize with it, as in the beautiful drawing of Michael Angelo of the head of Cleopatra, the outline seeming in many places to fade away, and the half tones to vanish insensibly; but to demand this of the young student is to demand of him that which only a cultivated taste and a great master can accomplish. That this system of teaching has a bad effect on the painter's after work is painfully evident in many of the pictures that hang on the walls of our exhibitions. Tutored at the outset to a fretful and inharmonious style, they seem to be unable to emancipate themselves from it in after years, for the same want of harmony and unity prevails in the pictures as in the drawings. There is no knowledge of tone or composition, and the consequence is a disturbed and unsettled effect, that is sometimes almost bewildering. Whether this may have anything to do with producing the academy headache I don't know, but it certainly is most distressing to those who are seeking for and who love the beautiful.

TONE.

Tone is another very important thing to study, if we wish to give the effect of atmosphere and space. It is a very subtle quality, which seems to ignore details and to deal with each portion of a work as a mass or surface of light or shade or half shade; and it deals with these masses in such a way that at a little distance the effect of a finished picture is produced, although when you go close to it you can scarcely make out what it is, owing to the absence of detail. Proper tone really gives more finish to a picture than very minute detail, for it means the just amount of light and shade and half-tone that objects, at different distances and in certain positions, must possess, and it also takes into consideration the values of the local colors of those objects, as, for instance, the value of a white turban on a swarthy head against a warm, gray wall or a blue sky; and it is of such importance that a picture which is out of tone is like a musical instrument that is out of tune. And in finishing a picture it is better to sacrifice detail than to sacrifice tone, for the one may be like a word of the song, but the other is like a note of the music—the one if wrong will scarcely be perceived; the other, if wrong, produces palpable discord. We often see pictures that at a distance look unfinished, though when we approach them we see they are very highly wrought—these are out of tone; and, on the other hand, those that appear finished at a distance seem but mere daubs or smudges when we go too near them—these are nothing else but tone. But the real art is to combine the two qualities, as all great painters do. To be a tonist only is to be the ninth part of a painter only. He is but one of the muses that makes up the choir of Apollo—he plays chords on canvas as another might play chords on the piano; but if neither the painter nor the musician ever go beyond that, we certainly cannot look upon them as great composers.

FINISH AND DISTANCE.

Very high finish, or rather a great insistency of detail, has a tendency to diminish the apparent size of distant objects. I saw some very minute water-color drawings the other day, which, though beautifully done, had a Lilliputian look, and did not possess the space that Turner gives to drawings of the same size, or that Mr. Whistler has given in his last series of etchings; they were stippled like miniatures, not touched with a subtle touch, which eludes the eye and captivates the imagination; the consequence was that all seemed to come forward, and appeared tiny. I remember another instance of this in a very good picture by a brother artist, which I saw in progress. It was a subject in which life sized figures were represented in the first plane, and in the middle distance there were several figures arranging a banquet. These were properly quite small, and he had suggested them with a few masterly touches, which rendered them admirable; they had just the right amount of finish for their size and distance, and I did not think that they required another touch; but he was not satisfied with them, and finished them up with the same care as his foreground figures, and so brought them into the foreground; and instead of appearing like life-size figures in the distance, they looked like little figures standing on the heads and shoulders of those in the first plane of the picture.

FINISH LEAVES NOTHING TO THE IMAGINATION.

Finish (so called) leaves little or nothing to the imagination. A life-size figure should be completely finished, as in Vandyke's portraits or the antique sculpture. But as the size diminishes the finish should be less; for, in order to keep up the illusion of life-looking, the aid of the imagination must be elicited. It is for this reason that Turner's drawings look so right. There is just the required amount of finish, and no more, for their size; but each line and touch so rightly directs the mind, that the imagination finishes the picture. Suppose we have to draw a figure about 3 in. high, we must place our model at that distance from us which perspectively reduces him to 3 in. We must then consider how much detail we can really see. We cannot see his eye-lashes, so we must not paint them; nor can we count the hairs in his mustache. Indeed, we can scarcely see his features at all. To give him his right size, we must leave out all detail that we cannot see, for if we do otherwise we destroy the distance, which is the only reason for the figure appearing so small. This, of course, applies to all other objects: ships, for instance, a long way off; if the masts, and the sails, and the ropes, and the portholes are made out too distinctly, lose in size, and look like little toys floating upon the water instead of ponderous hulks, great floating towns plowing and plunging through the ocean.

HOW AN ARTIST SHOULD FINISH HIS PICTURE.

The artist in finishing his work should not sit close to it (unless, like Turner, he is sure of his effects), but should stand back at least twice the length of his frame; at that distance he can take in the whole picture at a glance, and study the proper relation between the tones and the distance, and the sizes of the different objects in the composition. all that is unimportant disappears, and the exact amount of finish can be decided upon; standing at this distance with palette and brushes in hand, and noting each thing, he can go up to his work and put on the touch required, often obliterating small detail, then retiring to see the effect of his touches. This he does until the whole picture looks right from that distance, and these touches which make it look right are the finishing touches.

M. PHILIPEAUTEAUX'S PANORAMA OF PARIS.

I believe that when M. Philipeauteaux was engaged on the panorama of the siege of Paris (which was more like reality than anything I have ever seen on canvas), after all the drawing had been got in from the sketches, he himself sat in the center of the platform from which it was to be viewed, and directed his workmen as they painted in the sky, and the distance, and the various objects around, as to the tones and colors they were to use, saying this is too dark, that too light, and so on; but the sketches must have been very true that the panorama was painted from, for the effect was so perfect, that when I went up to see it it did not look like a picture at all; it seemed that I was standing on a tower in the open air, actually looking round Paris on a dull day, and I wished I had brought my opera-glasses, that I might look at those hills about ten miles off, when really they were painted on a canvas that was only a few feet from me. I heard that Mr. Pettie, the artist, was so struck by the perfect illusion that he could not believe he was standing close to a painted canvas, nor could he be disillusioned until he had jerked one or two pebbles at it, which caused a slight tremulous movement, and then he was convinced how near it was to him.

ATMOSPHERE AND SPACE FOR THE MIND.

If the object of studying this subject of atmosphere and space were merely to produce illusion, then it could not be said to be a very high one; but it seems to me that there

is something deeper behind it. We have seen that it is necessary to the production of good art and good workmanship, that it forms an important chapter in the grammar of art, but it enters also into the æsthetics of art. The healthy mind seems to have no innate idea of limit; it delights in the contemplation of boundless space and infinite existence. There is a subtle connection between the space which the painter represents on his canvas and the high level of his mind. A painter like Turner, who can take the eye of the spectator miles and miles into his picture, can also impress the mind with deep and great thought, for his conceptions are as grand as his distances are great. You have but to go to the National Gallery and study his works there, both in oil and water-color, or to look attentively through the Liber Studiorum, to be convinced that great thought is there, and that in pleasing the eye he appeals strongly to the imagination. This is high art, and shows that the painter, to be truly great, must not only give atmosphere and space to please the eye, but must also put into his work his whole heart and soul to produce atmosphere and space to delight the mind.

MODERN WORK.

In these days we look more to facts than to fancies, to details rather than to general impressions. If we paint a hero of history, the first that is looked to is correctness of costume; it must be archæological. Paul Veronese, in his magnificent scripture subjects, introduced the gorgeous Venetian dresses of his time; but these things are not tolerated now, and the difficulty is to decide which is preferable. I should say that good modern art is truer, in fact, is more photographic than ancient art, but on the other hand, it puts a bridle on the imagination, a bit in the mouth of Pegasus, and rides him with a curb. You have correct facts, but do they constitute fine art? They appeal to our knowledge, do they appeal to our hearts? Modern art is insistent; it stands out, it aims at being strong, not to say violent, but is it so gentle, so comfortable to have figures walking out of the frames as retiring into them? Does not a too great insistency of facts have the same wearisome effect upon us as too much of the care of every day life? Are they not very often like parochial rates, income tax, quarter's rent, and butcher's bills? In art do we not look for rest, for the getting away from these same little facts, this same loud assertion of superficial truths, and would we not rather live with pictures that do not assert themselves at any moment, but hang quietly on our walls like color-giving gems, whose radiation is calm and mysterious? Such works may have all the qualities of atmosphere and space, without ever telling us how clever they are, and such are the great works that have stood the test of ages.

There are still many things connected with this subject that we cannot enter into to-night. The sky, the sea, and the great turmoils of nature we must leave to another time—also the joyous effects of the sun in our rooms and on our housetops, the pleasant shades of evening, full of sweet sadness and strange fancies, the long-drawn shades of moonlight and the ghostly mists, dark forms reflected deep down in our rivers, and the hush of solemn midnight; nature will teach you all these things, if you desire to learn them, and art will interpret them to you in her best and most lovable works.

F. SCHAPER'S RESTORATION OF THE HERMES OF PRAXITELES.

THE results of the excavations at Olympia, carried on under the auspices of the German Empire, do not prove to be as satisfactory to the general public as they have been to science, for the public does not fully recognize the vast importance of single works as members in an unbroken chain of developments in art, but treats them as complete in themselves. The sculptures in the Temple of Zeus, and other works of art of very great archæological value, did not create much excitement among the general public, but, on the contrary, were quite a disappointment to many. However, the Nike of Pæonios and the Hermes of Praxiteles, two statues of noble beauty which far surpass all others found in Olympia, more than compensate for this disappointment. From an artistic point of view, the statue of Hermes with the infant Bacchus is more worthy of attention than that of the Goddess of Victory, while the celebrated name of the sculptor of the Hermes statue naturally makes it the center of the greatest interest.

When the statue of Hermes was thrown or fell from its pedestal, it seems that the raised right arm broke the force of the fall, and preserved the face of the statue from injury. Earth and rubbish then accumulated on the marble, and at the time that the statue was exhumed the head and face were as perfect as when viewed by the contemporaries of the artist. Not only the head, but also the body of the youth down to the knees, was preserved almost perfect, and with it the trunk of the tree, the garment draped on the same, the left arm resting on the trunk, the half-closed left hand, of which only the points of two fingers were missing, and finally the torso of the infant Bacchus were preserved, the position and action of the latter being established beyond a doubt by the fact that the right hand of the child rested on the shoulder of the god, the remnants of the right hand of the infant being still found on the statue. Later on the sandaled right foot of the Hermes and the head of the infant Bacchus were found, so that only the legs and the raised right arm of the main figure and the arms of the child were missing.

Prof. Schaper, of Berlin, has restored the statue, and made a plaster cast of the restored figure, an illustration of which, taken from the *Illustrirte Zeitung*, is given herewith. Prof. Schaper is one of the greatest German artists of the present time, and is especially qualified to fully conceive the spirit of the works of Praxiteles. The artist placed a cluster of grapes in the raised right hand of the Hermes, and the hands of the child are raised toward the grapes; and this seems perfectly natural, for Bacchus, as the God of Wine, would have a desire to obtain the grapes. There is very little doubt that this conception is correct, although it is claimed that if it were so, Hermes would have his head turned more toward the child than it is in the statue. But whoever fully understands the character of Praxiteles' art will know that that would by no means be a necessity with him. It has been claimed that the statue should hold the herald's staff in its right hand, but Mr. Schaper declared it impossible to place the staff in the small opening in the hand, and proved that the weight of the child resting on the left arm was sufficient to contract the muscles to such an extent that the hand would be closed more or less. Probably another examination of the original would remove all doubt in relation to that point.

TASAR SILK.

A REPORT from Major G. Coussmaker, superintendent of the Government Photozincographic Office, to the Secretary to the Government, General Department, on tasar sericiculture in the Bombay Presidency, dated Poona, 14th February, 1883, has been communicated to the Society of Arts by the Secretary of State for India. This is the last report which Major Coussmaker will make on the subject, and he does not recommend Government to continue these experiments, as there seems to be very little prospect of their proving remunerative, owing to three causes: (1) A very large supply of wild silk is now exported from China, and the price of "tasar waste" has in consequence fallen to 1s. 3d. per lb. in England; (2) the tasar cocoons of the Bombay Presidency are smaller and contain less silk than those found in other parts of India; (3) the expense of collecting cocoons, or of rearing the worms in a state of semi-domestication, as he had done, is great. Major Coussmaker proceeds:

In paragraph 4 of my No. 2 of February 3, 1882, I mentioned that I had sent home to Mr. Wardle the collections which I had made in two years. He sold these cocoons, weighing altogether 197 lb., to Messrs. Clayton, Marsden & Co., of Halifax, at 1s 3d. per lb., and sent me the money, which amounted to Rs. 146-14-0. The spinners report that "the fiber from these cocoons is somewhat coarser than most tasar waste, and the cocoons have been opened, but this is not a serious drawback to its spinning qualities. China is now sending over such large quantities that the price of tasar waste is very low." I do not think that the cocoons can be collected from the forests at a cheaper rate than four annas per hundred, and this is too high to admit of any profit. The collections made have fallen off considerably, and it is only through the personal exertions of the officers and guards of the Forest Department that I have received as many as I have. I found the same thing myself when I was out in the districts. In whatever village I was encamped, I could get the children to collect for me, but the price was not high enough to induce men to leave their work and look for cocoons. The village trader took no interest at all in the matter. I have tried, nearly every year, to increase the size of the cocoon, by importing some of the large variety from Sambalpur, Yamtasa, Manbhoom, etc., but with no success. The moths have paired readily with the small Deccan variety, the worms have hatched out, but there has been no difference in the cocoons, and I believe that the climate is the unsurmountable obstacle, though, perhaps, the difference of food may be another cause. As far as quantity is concerned, the result of rearing the tasar silk-worm in semi-domestication is most satisfactory. I have now been able to gather, within six weeks, three cocoons per running foot of hedge. My first worm, this last season, was hatched on 9th May, and the first cocoon was gathered in 32 days' time. Of this particular batch of worms, I took careful notes; they numbered 380, and 347 of them spun cocoons, commencing on 7th June and ending on the 24th June. They consumed 119 running feet of hedge, a few feet of which consisted of cuttings that had been kept growing for a twelvemonth; but the greater part of their existence was spent on a lagerstrœmia hedge, which on the 1st May had been cut down to 2 feet in height, cleared of every twig and vestige of a leaf, irrigated every third day, and inclosed within tarred screens of split bamboo, over which a coarse cotton covering had been stretched on rattan hoops; as fast as this hedge

PRAXITELES' HERMES RESTORED.

was eaten off, it sprouted again, and by the time the worms had reached the far end, the new shoots on the first tree were covered with leaves. Of the 1,800 feet of lagerstrœmia and zizyphus which I have now got, one-half was was sufficiently grown to yield a steady supply of food, and of this extent of hedges I gathered in May to October 5,678 cocoons; but, as in former years, I noticed that only 50 per cent. of these were sound and perfectly formed, and these were almost all gathered before the end of July. Later in the season I lost, without any apparent cause, many hundreds of worms in all stages; some being the progeny of moths of the former year, and some of this under review. Still, there were many cocoons spun, some of which were very fine, but the majority were weak and thin. My method of protecting the worms and insuring a steady supply of food is most effective. The labor bill is reduced to a minimum; one woman and one boy can easily look after an acre of hedge, if not more, and keep the inclosures in repair; but it must be borne in mind that if the monsoon does not break early and heavy, it will be necessary to water the hedges, and also the expense of inclosing is so very heavy that, as long as the price of tasar keeps low, this system cannot with profit be followed. In the neighborhood of dwellings, crows, sparrows, squirrels, and rats will collect, and must be kept out; this I succeeded in doing with material always available in India, but it is an expensive process. I used bamboo, buying it and making it up into chicks or screens, at Rs. 2 per 100 square feet; rattans, of which 10½ feet weigh 1 lb., at Rs. 3 per 1 lb; course cotton cloth at Rs. 2-2 per 11 running yards; iron rods, two inches in circumference, at Rs. 4 per 100 feet; common country string and tar; but at these rates the inclosing of an acre of hedge costs an initial outlay of Rs. 3,915-12, with a yearly expenditure of Rs. 305 to keep it in repair, and at the present price of tasar waste only Rs. 23 can be expected from the 20,205 cocoons which an acre of hedge would yield. I am here calculating for the one good crop which would only be on the ground, or rather on the hedge, between 1st May and 31st July; but the land would for nine months of the year be available for other crops. Perhaps some other experimentalist will be able to hit upon a cheaper method of inclosing.

I have only attempted the collection of tasar waste; it is most probable that the production of perfect dry cocoons ready for the reeler or reeled raw silk may be more remunerative; but the first problem I set myself was how to secure a steady supply; and until I had solved that I had determined not to attempt anything more. Ten years ago, Messrs. Lister & Co., of Bradford, in a letter to me on the subject, wrote: "It will pay best to let all the moths fly, and sell the burst cocoons." I think that it is apparent, from what I have mentioned already in this report, that the production of burst cocoons, *i. e.*, tasar waste, will not pay.

It is well known that the great objection to this silk was its natural color and reputed inability to take dye satisfactorily. Mr. Wardle has made a persistent series of experiments to overcome these defects, and informs me that he has now perfectly succeeded, and there will always be a demand for clean, evenly reeled tasar silk thus bleached.

Major Coussmaker concludes his report thus: I have now wound up my series of experiments, having year by year reported on what I have learnt, and can only regret that the conclusion is so very adverse to the prospect of the tasar silk industry in this Presidency.

ON THE ACTION OF CHLORINE ON CERTAIN METALS.

MR. RICHARD COWPER, of the Royal Naval College, has just recorded the results of some experiments on this action, especially that of dry chlorine on sodium, which are of considerable interest. He calls attention to the original observation of Wanklyn published a considerable time ago in the *Chemical News*, but up to this time never repeated or inquired into, although, as it appeared to us up to the time of the announcement, sufficiently curious to have attracted the attention of chemists. He it was who first noticed the inability of dry chlorine to act on sodium. Cowper had noticed that on attempting to burn sodium in an unusually dry sample of the gas the bright surface of the melted metal tarnished very slowly. He placed a piece of sodium in a glass tube and passed over chlorine which had first been subjected to the drying action of calcium chloride; the metal was heated to dull redness. It was then allowed to cool in the current of the gas, and the tube was sealed. The sodium was then raised to the melting point and shaken so as to cause the metal to flow from its slag-like envelope. At first it became dulled, but after several times causing a fresh surface to be exposed to the chlorine, it remained bright, the atmosphere in the tube being at the same time quite yellow, showing that very little chlorine had been absorbed. The action observed on first exposing a bright surface of melted sodium to the chlorine is no doubt due to the gas being imperfectly dried. If dried chlorine be passed over a piece of potassium, the latter catches fire. This is, however, probably due to the heat caused by the action of the chlorine on the envelope of KHO, which surrounds the piece of potassium. Some potassium was next sealed up in a tube containing dry air. The metal was then heated until all the oxygen was absorbed and a bright surface of potassium obtained. The tube was then filled with dry chlorine—dried by passage first through chloride of calcium tubes, and then through a tube packed with thin zinc-foil. The potassium at first remained bright, but slowly became covered by a film of a rich purple color. This is no doubt the sub-chloride described by Rose. The action was much accelerated by raising the metal to its melting point; the potassium did not, however, burn until the temperature greatly exceeded the point of fusion. When Dutch metal is introduced into a vessel containing chlorine, combustion takes place, accompanied with evolution of light and heat. It was found, however, that chlorine dried in the manner aforesaid acts very slowly upon it. Some Dutch metal was closed up in a thin glass tube with some pieces of calcium chloride, and placed in a larger tube with further calcium chloride; into this dry chlorine was conducted, and this was then sealed up, and after this had stood several days the little inclosed tube was broken inside by shaking, and the leaves of Dutch metal exposed to the action of dry chlorine. The metal remained bright, and after exposure for three months is still apparently unacted upon. If a drop of water be now allowed to come in contact with the metal, combustion takes place, accompanied with evolution of light and heat. Metallic zinc in thin foil is also unacted upon by quite dry chlorine, and appears to offer a highly advantageous means of removing the last trace of moisture from chlorine. Experiments were made with a number of metals after the chlorine had been in contact with calcium chloride for several days, with the following results: Magnesium, in the form of wire, was not attacked; silver, in the form of a leaf, was attacked very slowly. The presence or absence of light appeared to make no difference in the rate at which the metal was attacked. Bismuth was at first apparently unacted upon. After several days a specimen in the form of coarse powder had become slightly tarnished; but the atmosphere in the tube remained yellow. Tin, in the form of foil, was rapidly attacked with evolution of heat; antimony and arsenic, in the state of powder, were acted on immediately with evolution of light and heat. It may be noted that the last three elements produce chlorides which are liquid at ordinary temperatures. Mercury appears to be acted upon by the dry chlorine as rapidly as by the moist gas.

SIR WILLIAM SIEMENS ON SOLAR PHYSICS.

SIR WILLIAM SIEMENS lectured recently at the Royal Institution on "Solar Physics." The lecturer said that Comte in his "Positive Philosophy," as translated by Miss Martineau, had stated that one of the things which man could never do was to tell what the sun was made of, yet but a few years later Kirchhoff and Bunsen took the first steps toward the solution of the problem of the chemical constitution of the sun; and at the present time, by the revelations of Lockyer, Huggins, and others, much has been made known not only as to the nature of the sun, but of the stars also. As to the temperature of the sun great diversity of opinion exists, various astronomers, including Sir Isaac Newton, giving it a temperature of several millions of degrees Centigrade; whereas Dulong, Petit, and others had estimated it at less than 1,800° C. The solar radiation could be compared with that from other sources of heat, and when tested by this experimental method, it had been concluded that the temperature of the photosphere must be something like 10,000° C.; yet if the heat of the photosphere exceeded 3,000° C., combustion therein would be impossible, for dissociation would take place, and this would negative the hypothesis he had to place before them that evening.

The earth, he added, is situated at close upon 100 diameters of the sun from the center of that orb; consequently, if ordinary conditions prevail, the heat of the sun when it reaches our earth is $\frac{1}{10000}$ of that at the photosphere. The light and heat of the sun are not lost on the way to the earth, except by absorption. Much of the heat of the sun misses the planets, and is radiated away into space; nobody can tell what becomes of it there. In making new researches a working theory must first be put forward to be criticised as much as possible, for science advances only by speculation in the first instance. He had put a hypothesis before the scientific mind whether it is not possible that the heat of the sun is intercepted and sent back to him; and to support this hypothesis he soon found out that he must prove that the solar photosphere had not a temperature higher than 3,000° C. at the outside.

Accordingly, he first of all mounted a parabolic mirror upon a heliostat; if there were no medium between the earth and the sun, all the parallel rays from the sun falling upon the mirror would be concentrated at its focus, and reproduce approximately the solar temperature. The losses by absorption in the atmosphere and at the surface of the mirror were but small. When a piece of carbon was placed in the focus it became very hot, and almost as luminous as the electric light. When a gas flame was placed in the focus there was retardation of combustion, but not arrest, showing that the heat was not greater than that produced by a Deville furnace.

He next brought the spectroscope to bear upon the problem. Two and a half per cent. only of the rays from the Argand oil flame were luminous; in the incandescent electric light five or six per cent. of the total radiation was luminous; of the radiation from a 5,000 candle electric arc light, 25 per cent. was luminous. Prof. Langley, by his experiments in the Alleghany Mountains, had proved that not more than 25 per cent. of the solar radiation was luminous, which again led him—Sir W. Siemens—to the conclusion that the heat of the photosphere was not greater than that of the electric arc or of a powerful furnace. Sir William Thomson had expressed the opinion that the solar temperature was not higher than 3,000° C. If it were much higher the sun would become blue, its light would diminish, and the increase in the violet and ultra-violet rays would kill all vegetation. Still, all he had said did not amount to positive proof; but he had before him a platinum wire 4 ft. 6 in. long, suspended between two screws across the front of the lecture table. An electrical current would be sent through it, and measured by a dynamometer. The potential of the current would also be measured by a resistance galvanometer, the product of the two readings giving volt-amperes, or units of energy. He could thus get at the temperature of the wire—the temperature being measured by its electrical resistance—as well as at the amount of energy radiated, and thus he obtained a curve. By this method of experimenting the melting point of platinum was shown to be about 1,800° C., and by the same formula the temperature of the solar photosphere was 2,750° C.; Sir William Thomson, by means of researches on spectra, had come to the same conclusion.

Assuming the temperature of the sun to be as low as this, if fuel and oxygen were to meet at its surface, combustion could take place. If space were assumed to be full of hydrocarbon vapors, which Captain Abney and certain other men of science asserted to be the case in fact, here was the supply of fuel. His hypothesis assumed an inflow and outflow current at the sun's surface—the former at the poles, the latter at the solar equator. It might be asked how the products of combustion came back to the sun as materials for combustion. Will the solar ray acting on attenuated vapor dissociate it? He was attempting to answer this question by some experiments not yet completed. Highly attenuated carbonic acid and aqueous vapor were not readily dissociated, yet in the tube he held in his hand their dissociation had been effected by means of exposure to direct solar rays and the light of the electric arc. When he first broached his solar hypothesis, the extension of the diameter of the atmosphere of the sun at its equator was not known; it had, however, been seen during recent eclipses, and Dr. Huggins, only the day before his lecture, had seen it without an eclipse.

During a pause in the lecture, caused by assistants trying to get Sir William Siemens' electrical furnace to work, with something wrong in the gas engine driving the dynamo, the speaker said that Professor Langley, of Alleghany Observatory, had made a heat measuring instrument so sensitive that an American newspaper had given it the credit of being competent to indicate the temperature of a cow a mile away. The farmer of the future, perched upon his central observatory with this instrument in his hands, might possibly thereby examine the temperature of individual members of his flocks and herds, and when necessary telegraph to his assistants that a particular cow needed a warm drink. He added that when copper was melted in the electrical furnace it had a tendency to fly off into vapor all at once soon after fusion. This might indicate that the temperature of the volatilization of metals was nearer that of fusion than is generally supposed.

REICHENBACH AND THE PSYCHICAL RESEARCH SOCIETY.

NEARLY forty years ago the scientific world and the more intelligent classes in general were startled by an announcement in Liebig's "Annalen." Baron Von Reichenbach, who, though not a chemist of the highest order, was still favorably known as an experimentalist, had observed luminous appearances over the poles of powerful magnets, at the ends of the axes of certain crystals, and upon a number of other bodies. These phenomena Reichenbach ascribed to a yet undiscovered form of energy, to which he gave the name of Od. At once not a few inquirers attempted to verify the author's results, but in general with but indifferent success. The misfortune was that, on Reichenbach's own admission, these lights were not visible to all mankind, but only to a minority, whose sight was abnormally delicate. The very name which had been selected was, for England at least, very unfortunate. The majority of our countrymen would persist in pronouncing it as if written *odd*, and thus affording scope for petty joking. Others made matters worse by tacking a classical tailpiece to Reichenbach's Teutonic monosyllable, converting it into *odyle*. Thus the idea was insinuated that the unknown something was not a phase of energy, but a material organic compound, analogous to ethyle, methyle, propyle, etc. Before very long *od* was dropped. The physicists ceased to experiment for, on, or with it, and, despite the august sponsorship of Liebig, it was handed over to that semi-scientific limbo where exploded delusions await decomposition and neglected truths their resurrection. Latterly, however, the Psychical Research Society have turned their attention to this subject, and have submitted Reichenbach's researches to a very careful and impartial revision.

The preliminary question may be raised, Why should the Psychical Research Society engage in an inquiry so purely physical? To this query it is not easy to give a satisfactory reply. Still the solution of a difficulty should be none the less welcome, by whomsoever it is furnished; all that we have a right to ask being merely, Is the solution genuine? The experiments undertaken by the Society, and described in detail at the meeting held in Willis' Rooms, April 24, 1888, if not entirely decisive, have upon the whole an affirmative character, and in short justify the public in concluding that "there is something in it." In other words, our verdict must be given in favor of Reichenbach, unless some quite unexpected source of error is detected on further experimentation. The persons chiefly engaged in the research were Prof. Barrett, Mr. W. H. Coffin, Mr. E. Gurney, Mr. E. R. Pease, Dr. A. T. Myers, Messrs. F. W. H. Myers, H. N. Ridley, and W. R. Browne. The experiments were made at No. 14 Dean's Yard, Westminster, in a perfectly darkened room. The first point to be considered is whether the darkness was truly absolute. It was asserted that not a glimpse of light was perceptible to "observers, even after an hour's immersion in the darkness." We understand, also, that the room was always darkened for a considerable time before the experiments began, so as to eliminate error from the possible presence of phosphorescent light. This precaution is the more necessary since our knowledge of phosphorescent bodies is far from exhaustive. From various considerations it is possible that most substances may be feebly phosphorescent. Hence the most satisfactory arrangement for the class of experiments in question would be a room permanently darkened. In the dark room was fixed an electro-magnet of the power of from 200 to 300 lb. Conducting wires were carried to a commutator in the next room, and thence to a 8mee battery of sufficient power. The room where the commutator was placed was separated from the darkened room merely by curtains, so that what was said in the one was distinctly heard in the other. In this darkened room, where was the magnet, were stationed, as we understand, Prof. Barrett, Dr. Myers, Mr. F. W. H. Myers, and Mr. Ridley. The commutator in the room on the other side of the curtains was in charge of Messrs. W. H. Coffin, E. Gurney, and E. Pease. It will be at once perceived that the three last mentioned gentlemen could, by making and breaking the current at such intervals as they thought fit, alternately create and annul the power of the magnet. Hence if a light was produced over the poles of the magnet on making circuit, and disappeared on interruption, it might be fairly concluded that the magnetism and the luminosity were causally connected.

The next point relates to the observers. Unfortunately not all persons are capable of perceiving this light Of forty-five subjects tested, three only were able to perceive anything. Of these three the most successful were a Mr. G. A. Smith and a boy, Frederic Wells. It is right to add that both these had been to some extent engaged in mesmeric operations. It is, however, expressly stated that "both of them were entire strangers to these experiments, and disclaimed any knowledge of Reichenbach's work. In the first instance they were not told what to look for, but merely to note if they perceived anything amid the darkness, and if so, what and where."

The English version of Reichenbach's work, by the late Prof. Gregory, is, we believe, out of print, and rarely to be met with. From the circumstance, however, that Dr. Ashburner repeated Reichenbach's experiments, the work is perhaps more known among persons who dabble in mesmerism than it is elsewhere. Hence, without pronouncing Smith and Wells to be tainted with imposture, we think it would be well if the experiments could be repeated with subjects not conversant with mesmerism.

We turn now to the experiments themselves, and consider in how far they demonstrate the reality of the phenomena sought for, and, as a necessary condition, how far they eliminate the possibility of trickery or collusion.

The operators being placed in charge of the commutator, and the observers being posted in the dark room, the sensitives, Smith and Wells, were introduced—as it appears, separately—and after some time each declared that he saw a faint light or a luminous vapor. Each declared that this appearance was over the poles of the magnet, the one—the so-called north pole, or rather north-seeking pole—being the brighter of the two. The light was pronounced to be in the form of wavering cones, running to a point where touching the magnets and growing wider upward. A current of air —*e. g.*, the breath—was said to drive the flame aside, but not to extinguish it. Various substances—such as a board, or a piece of velvet if laid in a flat position over the poles of the magnet—seemed not to affect the light, but it was at

once obscured if these objects were held between the magnets and the eyes of the "sensitives." If, as we understand, this interception was effected without their knowledge—as would be quite possible in a dark room—we have here valuable evidence of their good faith.

The most decisive proof is, however, the following: the sensitives always proclaimed that the light had disappeared whenever the current was interrupted. In a series of test observations made upon Smith, which lasted for more than an hour, contact was made or broken for fourteen times in succession. The intervals were intentionally varied from a few seconds to several minutes; yet, as the operators in the other room testify, Smith's exclamations, "It's there!" and "It's gone!" coincided exactly with the movements of the commutator. Hence it seems legitimate to conclude Smith saw the light when the current was established, but ceased to see it on interruption.

If this was not the case, we must have either casual coincidence or indications obtained in some other manner. The supposition of casual coincidence Prof. Barrett disposes of very satisfactorily. There are in an hour 3,600 seconds, in each of which there was an equal antecedent chance of the circuit being formed or interrupted. Hence the probability of even a single right guess is very small. But the chance against hitting fourteen right moments in succession, without a miss intervening, is so many millions to one that it may be practically dismissed as out of the question.

The more important consideration is whether the conduct of the experimentalists and observers, or any circumstances connected with the experiments themselves, might furnish the sensitives with a clew to what was taking place. On this subject we prefer to quote the exact words of Professor Barrett, in the *Philosophical Magazine*. He says: "Among such indications the so called 'magnetic tick' at once suggested itself. Knowing precisely what to listen for, and therefore more keenly alive to the sound than Smith, who presumably knew nothing of this molecular crepitation, I failed to detect the faintest sound of the making of the circuit, and a barely audible tick on breaking contact was heard only when my ear was in close contact with the magnet or its support. This was due to the massive character of the magnet and stand, which also prevented any other discernible movement when the magnet was excited. Further I satisfied myself that, at the distance at which Smith stood from the magnet, it was impossible to discover when the circuit was completed by the attraction of any magnetic substance about one's body; as a precaution, however, Smith emptied his pockets beforehand." Prof. Barrett adds, however, "At the same time it is quite possible a skillful operator, bent upon deceiving us, might be able to detect the moment of magnetization and demagnetization by feeling the movement of a concealed compass needle. Against this hypothesis must be placed the fact that no information was given to Smith beforehand of the nature of the experiment."

The possibilities of imposture are further greatly lessened by the experiments made with the boy Wells. His perception of the luminous phenomena appears to have been more acute and sensitive than that of Smith. In the preliminary trials he saw the light earlier than Smith had done. The flame, according to his description, was larger and brighter than it appeared to Smith. To the latter, moreover, the light on breaking contact disappeared immediately, and he accordingly exclaimed, "It's gone!" To Wells it seemed to die away, rapidly but not instantaneously, and he therefore said, "Oh, you are spoiling it!" Prof. Barrett here points out that there was still a large residue of magnetism left in the electro-magnet after the current was interrupted. We do not learn whether any experiments with permanent horse shoe magnets were tried with Smith; but with Wells some very valuable results were obtained in this manner. He saw the luminous appearance on the poles of both; when they were silently removed without his knowledge, he detected at once their new position. Says Professor Barrett, "Holding one of the magnets in my hand, Wells told me correctly whether I moved the magnet up or down, or held it stationary; this was repeatedly tried with success."

It was further ascertained that no effect was produced by these magnets upon a small compass-needle, even at one-tenth of the distance at which Wells stood. Hence the compass trick, to which Prof. Barrett referred, would in this case be ineffectual. Moreover, it is scarcely conceivable that a baker's shop lad would be familiar with this method of detecting magnetic action.

The next question which suggests itself concerns the compatibility of the luminous phenomena observed with known laws. We by no means mean to intimate that theories ought to override facts. But it will be granted that if some novel observation is found to be in harmony with our previous knowledge, we feel much better satisfied with its accuracy than if it appears irreconcilable and anomalous. If a luminous appearance hovers over the poles of magnets, it will not have arisen *de novo* as a creation of energy, but will be a work of transformation. In the case of the electro-magnet we have no difficulty; we have electricity converted into magnetism, and need feel little surprise if the molecular disturbance occasioned in the metal of the magnets, or in the air immediately in proximity to them, expresses itself as light, or as some other form of energy not yet known. Prof. Fitzgerald, F.R.S., refers to the well known fact that the gases of the atmosphere differ in their magnetic relations, oxygen being strongly magnetic, while nitrogen and carbonic acid are decidedly diamagnetic. Hence a process of molecular disturbance in contact with a powerful magnet is to be expected. Again, it is well known that the atmosphere holds in suspension minute solids, which have also their magnetic relations. To determine whether either or both, or neither, of these relations come here into play, he proposes an experiment to which we shall shortly refer.

But while these or some kindred theory may probably account for the luminosity over the poles of an electro-magnet in full accord with the great truth of the conservation of energy, the case might seem at first glance dubious with a permanent magnet. But here the question is raised whether there is not a very slow loss of magnetic power gradually and constantly at work, the energy thus lost reappearing as light, or, if any one prefers the term, as *od*.

The "Reichenbach Committee" of the Society for Psychical Research promise that, when the simple fact has been fully established, they will proceed to a further examination of the nature and properties of *od*. With all due submission we doubt whether the simple fact will ever be accepted as established until some progress has been made with these investigations. Prof. Fitzgerald, in order to test his own suggestions, recommends observations with a magnet in a medium approaching as nearly as possible to a vacuum. To this might be added experiments in air freed from suspended solids by filtration through cotton-wool; in pure hydrogen, in oxygen, in carbonic acid, and in other gases and gaseous mixtures. Further points are the passage of the od-light through lenses of power and nature unknown to the sensitive observer, its reflection from plane and concave mirrors, by which means all possibility of trickery could be obviated. Not less important is the spectroscopic, polariscopic, and photographic examination of the light.

It does not appear that the Committee have as yet attempted to verify Reichenbach's original experiments with crystals, and on a number of other bodies. Thus there is indeed a vast assortment of work awaiting them—some of it, as we must admit, of no small difficulty. But while we would warmly encourage these investigations, and are prepared to welcome the results, whether the phenomena are traced to *od* or are merely novel manifestations of some form of energy already known, we must again express our inability to recognize their connection with psychical research, and still less with spiritualism. As far as we see, there is in Reichenbach's phenomena nothing which need be unacceptable even to the most determined positivist, or to any one who regards the phenomena commonly attributed to soul, spirit, or mind as the mere outcome of organization. True, certain persons can perceive the magnetic luminosity, while others fail so to do. But this fact seems to us to stand upon the same plane as the well-known differences between man and man in the recognition of colors, in the perception of remote or minute objects, and in the hearing of very acute sounds.—*Journal of Science.*

THE LUMINOSITY OF NON ILLUMINATING GAS FLAMES.

As the illuminating power of gaseous flames is known to be due to the presence of incandescent solid or even liquid particles, it has been customary to say that the feebly luminous flame of gases which do not contain such particles is the effect of the incandescence of the gas itself at a high temperature. Dr. Werner Siemens had an idea that pure gases, however highly heated, did not emit light; and he has recently carried out a series of experiments to determine this question. In order that an experiment of this nature should be decisive, the observed temperature should be higher than that produced by luminous combustion. Dr. Werner Siemens therefore had recourse to the regenerative furnace used by his brother Friedrich Siemens, of Dresden, in the manufacture of hard glass. The furnace stands in a separate room, which can be made perfectly dark. In the walls of the furnace are two openings opposite each other, thus allowing free vision through. A heat of 1,500° or 2,000° C. (or beyond the melting temperature of steel) can easily be obtained. Before the sight holes were placed a series of smoke-blackened screens, with central openings so proportioned to the holes in the furnace that the observer could look through the latter without receiving any rays from the heated walls. If under these conditions dampers were closed, and all light excluded from the room, it was found that not the least light came to the eye from the highly-heated air in the furnace. For the success of the experiment it was necessary to avoid any combustion in the furnace, and then wait until the inclosed air was as free from dust as possible. Any flame in the furnace, even when not in the line of sight, or the least quantity of dust in it, illuminated the field of vision. As a result of these experiments Dr. W. Siemens considers the view hitherto held, that highly heated gases are self-luminous, is not correct. In the furnace were, in this instance, the products of the previous combustion of the fuel with atmospheric air; or a mixture of oxygen, nitrogen, carbonic acid, and aqueous vapor. If only one of these gases had possessed the property of being self-luminous, the field of vision must have been always illuminated. The weak light of burning gases wherein there is no separation of solid particles cannot, therefore, be considered as a phenomenon of the glow of the gaseous products alone. It further occurred to Dr. W. Siemens as probable that heated gases do not emit heat rays. After again convincing himself, and Dr. Herr Fröhlich, of Dresden, that the heated gases were perfectly dark, Dr. W. Siemens' thermopile experiments for the investigation of the other hypothesis failed. By the aid of a common lamp, however, it was found that heated gases do radiate some heat, but much less than solid bodies at the same temperature. Dr. W. Siemens does not yet say what he believes to be the cause of the feeble light of so-called non-luminous gases.

ON RADIANT MATTER SPECTROSCOPY: A NEW METHOD OF SPECTRUM ANALYSIS.*

By WILLIAM CROOKES, F.R.S.

For several years I have been examining the phenomena presented by various substances when struck by the molecular discharge from the negative pole in a highly exhausted tube. I have ventured to call this discharge "radiant matter," and under its influence a large number of substances emit phosphorescent light, some faintly and others with great intensity. On examining the emitted light in the spectroscope most bodies give a faint continuous spectrum, with a more or less decided concentration in one part of the spectrum, the superficial color of the phosphorescing substance being governed by this preponderating emission in one or other part of the spectrum. Sometimes, but more rarely, the spectrum of the phosphorescent light is discontinuous, and it is to bodies manifesting this phenomenon that my attention has been specially directed.

For a long time past I have been haunted by a bright citron-colored band or line appearing in these phosphorescent spectra, sometimes as a sharp line, at others as a broader nebulous band, but having always a characteristic appearance and occurring uniformly in the same spot. The best way to bring out the band is to treat the substance under examination with strong sulphuric acid, drive off excess of acid by heat, and finally to raise the temperature to redness. The anhydrous sulphate thus left frequently shows the citron band in the radiant matter tube, when before this treatment the original substance shows nothing. I soon came to the conclusion that the substance I was in search of was an earth, but on attempting to determine its chemical properties I was baffled.

Much chemical evidence tended to support the view that the band might be due to a compound of lime. By neglecting the portion showing least citron band, and separating all the elements present which gave little or none, I could generally concentrate the citron band into a solution which—according to our present knowledge of analytical chemistry—should contain little else than the earths, alkaline earths, and alkalies. Ammonia added to this solution would precipitate an earth, and in the filtrate oxalic acid would precipitate an insoluble oxalate, showing the citron band strongly. This was found on analysis to consist of strontic and calcic oxalates. The strontia being separated, the remaining line formed an oxalate which gave the citron band.

So far all the chemical evidence went to show that the band forming substance was calcium, and further tests tried with the purified oxalate confirmed this inference. Every analytical test to which it was subjected showed lime, and nothing but lime; all the salts which were prepared from it resembled those of lime, both physically and chemically; the flame spectrum gave the calcium lines with extraordinary purity and brilliancy; and, finally, the atomic weight, taken with great care, came out almost the same as that for calcium, 39·9 as against Ca 40.

On further examination it was found that most native compounds of lime gave the citron band. It was found in clear and colorless Iceland spar, native calcic phosphate, a crystal of arragonite, a stalactite of calcic carbonate from Gibraltar, cinnamon stone (lime alumina garnet), iron slag from a blast furnace, pink coral, commercial plaster of Paris, and most specimens of ordinary burnt lime.

Evidence stronger than this in favor of the view that the citron band was an inherent characteristic of calcium could scarcely be; but on the other hand, there was evidence equally conclusive that the band was not essential to calcium.

Starting with a lime compound which showed the citron band, I could always obtain a calcic oxalate which gave the band stronger than the original substance; but if I started with a lime compound which originally gave no citron band, I could never by any means, chemical or physical, constrain the lime or the earthy precipitate to yield a citron band.

The only explanation that I could see for this anomaly was that the elusive citron band was caused by some element precipitated with the calcic oxalate, but present in a quantity too small to be detected by ordinary chemical means. The calcic oxalate was ignited and dissolved in hydrochloric acid, and fractionally precipitated in three portions with ammonic oxalate, the first and third portions being comparatively small. They were then tested in the radiant matter tube. All three portions showed the citron band, but the portion which came down first gave the band decidedly the strongest, and the third portion precipitated showed it weakest.

It having been found that the substance giving the citron band formed a sulphate more soluble in water than calcic sulphate, four pounds weight of commercial plaster of Paris, which showed very faint traces of the citron band, was mixed with water and poured on a large filter. A few ounces of water were poured on, and after passing through, poured back, and the exhaustion repeated several times. The aqueous extract was then evaporated to dryness, ignited with sulphuric acid, ground in a mortar with small successive quantities of water, and precipitated with ammonic oxalate. The precipitate, ignited with sulphuric acid, showed the citron band very fairly, far more intensely than it was seen in the original calcic sulphate.

These experiments are conclusive in proving that the citron band is not due to calcium, but to some other element, probably one of the earthy metals, occurring in very minute quantities, but widely distributed along with calcium, and I at once commenced experiments to find a more abundant supply of the body sought for. Among other substances tested I may note the following as giving a more or less decided citron band in the spectrum when treated with sulphuric acid in the manner indicated above:

Crystallized barytic chlorate, heavy spar, common limestone, strontic nitrate, native strontic carbonate, crystallized uranic nitrate, commercial magnesic sulphate, commercial potassic sulphate, tobacco ash, Wagnerite (magnesic phosphate and fluoride), zircon, cerite, and commercial ceric oxalate.

Some specimens of zircon appeared sufficiently rich to make it probable that here might be found an available source of the citron band yielding body. I found it in crystals from Green River, North Carolina, from Ceylon, from Expailly, from Miask (Oural), and from Brevig, and having a good supply of North Carolina zircons, these were worked up by a process given in detail in the paper.

I may condense a year's work on zircon—over 10 pounds weight of crystals from North Carolina having been worked up—by stating that the result was comprised in about 300 grains of an earthy residue, and about 2 ounces of oxalate, chiefly calcic; the former gave the citron band very well.

The zirconia prepared from these zircons, when tested, sometimes showed the citron band, and at other times none. A zirconia rich in citron band, fractionally precipitated by ammonia, yielded precipitates of increasing richness, the last fraction showing the citron band strongly.

The calcic oxalate obtained from zircon gave unsatisfactory results, so attention was directed to the earthy residue.

This was found to be of highly complex character, containing thoria, ceria, lanthana, didymia, yttria, and probably some of the newly discovered rarer earths.

The position of the citron band in the spectrum falls exactly on the strongest absorption band of didymium, so that a piece of didymium glass or cell of solution of the nitrate entirely obliterates the citron band. This naturally suggested that the band was due to didymium.

Cerite was accordingly the next mineral experimented on. The powdered mineral tested in the tube in the original way gave a good citron band. The mixed earths after extraction were converted into sulphates, dissolved in water, and the cerium metals precipitated by long digestion with excess of potassic sulphate.

The precipitated double sulphates were converted into oxalates, and after ignition and treatment with sulphuric acid, the mixed ceria, lanthana, and didymia were tested in the radiant matter tube, but the merest trace only of citron band was visible.

This explanation proved the inadequacy of the didymium explanation, and further tests showed that not only could I get no citron band in pure didymium compounds, but the spectrum entirely failed to detect didymium in many solutions of the earth which gave the citron band brilliantly.

Attention was now turned to the solution filtered from the insoluble double sulphates. Potash was added, and the precipitate filtered off and tested in a radiant matter tube. The spectrum, of extraordinary brilliancy, was far brighter than any I had hitherto obtained. Unfortunately, however, the quantity was too small to be subjected to very accurate chemical analysis.

Search was now made among other minerals, rich in the rarer earths. Thorite was finely powdered, treated with sulphuric acid, and tested in the radiant matter tube. It gave the citron spectrum most brilliantly—equal in fact to the mixture of earths obtained from zircons at so great an expenditure of time and trouble. Orangite treated in the same manner gave almost as good a spectrum. Pure thorinic sul-

* Abstract of the Bakerian Lecture delivered before the Royal Society, May 31, 1883.—*Chemical News.*

phate, prepared by myself, was found not to give the citron band, but three specimens prepared and given to me by friends all gave it, so it was not unlikely that in thorite and orangite might at last be found a good source of the long sought element—that in fact the body I was hunting for, if not thorina, might possibly be Bahr's hypothetical wassium. Two pounds of orangite and thorite were extracted with hydrochloric acid. The solution was precipitated with potassic sulphate, taking the usual precautions to secure complete precipitation. A bulky precipitate ensued, which contained the thorina and cerium earths. These were separated and tested, and found to give only a faint citron band.

The solution of earthy sulphates soluble in potassic sulphate was precipitated with ammonic oxalate. The precipitate ignited with sulphuric acid, and tested in a radiant matter tube gave the citron spectrum with great brilliancy.

Certain chemical facts concerning the behavior of the sought for element which came out during the course of the tentative trials described in the paper considerably narrowed the list among which it might probably be found. All the evidence tends to show that it belongs to the group of earthy metals, consisting of aluminum, beryllium, thorium, zirconium, cerium, lanthanum, didymium, and the yttrium family, together with titanium, tantalum, and niobium. The sought for earth is insoluble in excess of potash; this excludes aluminum and beryllium. It is not precipitated by continued boiling with sodic thiosulphate; this excludes aluminum, thorium, and zirconium. Fused with acid potassic sulphate, the resulting compound is readily soluble in cold water; this excludes tantalum and niobium. Evaporating to dryness with hydrochloric acid and heating for some time does not render the mass insoluble in water; this excludes titanium and silicium. It is easily soluble in an excess of a saturated solution of potassic sulphate; this excludes thorium, the cerium group, some of the numerous members of the yttrium group, and zirconium. The only remaining elements among which this elusive body would probably be found are those members of the yttrium family which are not precipitated by potassic sulphate.

The yttria earths form a somewhat numerous family. Fortunately for chemists, a mineral rich in yttria earths—samarskite—has been found lately in large quantity in Mitchell County, North Carolina, and to this mineral I accordingly now directed my attention.

The following list of elements of the yttrium and its allied families said to occur in samarskite and similar minerals may be considered complete to the present time:

Name.	Absorption spectrum.	Hydrogen equivalent of metal.* (Type of oxide M_2O.)
Cerium	No	47·1
Decipium	Yes	57·0
Didymium	Yes	48·5
Didymium β.	Yes	47·0
Erbium	Yes	55·3
Holmium	Yes	54·0
Lanthanum	No	46·0
Mosandrum	No	51·2
Samarium	Yes	50·0
Scandium	No	14·7
Terbium	No	49·5
Thulium	Yes	56·5
Ytterbium	No	57·9
Yttrium	No	29·7
Yttrium α.	No	52·2
Yttrium β.	Yes	49·7

Some of these claimants it is certain will not stand the test of further scrutiny. Thus, samarium and yttrium β are in all probability identical; and I have not included philippium, as Roscoe has conclusively proved that this is a mixture of terbium and yttrium, and my own results confirm those of Roscoe. Moreover, some of these so-called elements will probably turn out to be mixtures of other known elements. But in the confessedly very imperfect state of our knowledge of the chemistry of these metals it is not safe for me in this research to assume that any one of them will surely not survive. The complete list as it stands will therefore be taken to contain all hitherto claimed as new, although it is almost certain to include too many.

In the second column "Yes" or "No" indicates whether the solutions give an absorption spectrum when examined by transmitted light. After numerous experiments I satisfied myself that the metal giving the citron band spectrum was not one of those giving an absorption spectrum. The possible elements, therefore, became narrowed to the following list:

Cerium, lanthanum, mosandrum, scandium, terbium, thorium, ytterbium, yttrium, yttrium α, and zirconium.

Of these the potassic sulphate reaction excludes cerium, lanthanum, scandium, thorium, yttrium α, and zirconium; so there are left only the following:

Mosandrum,
Terbium,
Ytterbium,
Yttrium.

Certain chemical reactions for a long time made me dismiss yttrium from the list of likely bodies. In my analysis of zircons, toward the latter part of the process, I used the following process to separate the iron:

The solution mixed with tartaric acid and excess of ammonia was allowed to stand for some time. A small quantity of a precipitate gradually formed, which was filtered off, and it was this filtrate, after separating the iron with ammonic sulphide, that yielded the greatest quantity of substance giving the citron band. Now one of the methods of separating yttria from alumina, beryllia, thoria, and zirconia is to precipitate it as tartrate in the presence of excess of ammonia, the other earths remaining in solution. Fresenius says: "The precipitation ensues only after some time, but it is complete."

The precipitate thus obtained with tartaric acid and ammonia should therefore contain all the yttria; *it gave no citron band whatever in the radiant matter tube;* while the residue, which should be free from yttria, proved for a long time the only source of material wherewith to investigate the chemical properties of the body giving the citron spectrum.

Another reason which made me, at this stage of the research, pass over yttria, was that I had already tested this earth in the radiant matter tube. In a paper on "Discontinuous Phosphorescent Spectra in High Vacua," read before the Royal Society, May 19, 1881, I said, "Yttria shows a dull greenish light, giving a continuous spectrum."

For these reasons I for a long time omitted yttria from my list of possible bodies, and considered that the earth, if not a new one, might turn out to be either mosandra, terbia, or ytterbia.

About 15 pounds weight of samarskite was worked up, partly by the hydrofluoric acid method of Lawrence Smith, and partly by fusion with potassic bisulphate.

These methods both gave as a result a large quantity of mixed earths containing most, if not all, the bodies enumerated in the foregoing list. Tested in the radiant matter tube, this mixture gave the citron spectrum very brilliantly.

These earths were treated by a series of chemical processes too long and complicated to describe in this abstract, and the result of about five hundred fractional precipitations gave me a mixture of earths having an H equivalent, M=48, and showing a strong absorption spectrum; a mixture having an H equivalent, M=33, having no absorption spectrum; and intermediate earths.

In the radiant matter tube all these fractions gave the citron band spectrum well, but that of the earth of lowest equivalent was much the brightest, and that of the highest equivalent the least intense.

Three methods are available for the partial separation of these earths and for the complete purification of any one of them. The formic acid process is best for separating terbia, as terbic formate is difficultly soluble in water, the other formates being easily soluble.

Fractional precipitation with oxalic acid separates first erbia, holmia, and thulia, then terbia, and lastly yttria. This is the only method which is applicable for the separation of small quantities of terbia from yttria.

Fusing the nitrates separates ytterbia, erbia, holmia, and thulia from yttria. It is not so applicable when terbia is present, and is most useful in purifying the gadolinite earths. This process is the only one known for separating ytterbia from yttria.

Selection must be made of these methods according to the mixture of earths under treatment, changing the method as one earth or the other becomes concentrated on one side or thrown out on the other. Each operation must be repeated many times before even approximate purity is attained. The operations are more analogous to the separation of members of homologous series of hydrocarbons by fractional distillation than to the separations in mineral chemistry as ordinarily adopted in the laboratory.

Pure terbia ignited with sulphuric acid and tested in the radiant matter tube shows no citron band spectrum. A concentrated solution of the purest terbia obtained in this way, when examined by the spectroscope, showed no absorption lines whatever; proving the absence of erbium, holmium, and thulium.

I did not attempt any separation of erbium, holmium, and thulium from each other, as the evidence obtained was sufficient to show that the element giving the citron band spectrum was not one of these three metals. Likewise I had far too little material to enable me to enter on a work of such difficulty with any prospect of success.

The chemical characters of mosandra are so little known that I could not attempt to search for it. But as the citron band-forming earth always appeared concentrated among those whose double sulphates were most soluble in potassic sulphate—and, of these, among those having the palest color and lowest atomic weight—it was scarcely conceivable that the earth I was in search of should ultimately prove to be one whose properties did not in any case correspond to these—of a dark orange yellow color, forming a difficultly soluble double potassic sulphate, and having the very high equivalent of M=51·2; these being the properties ascribed to mosandra by the discoverer, Professor Lawrence Smith.

Ytterbia was prepared from gadolinite, as this mineral is said by Nilson to contain most ytterbia. It was separated from accompanying earths by processes described in the paper. The resulting earth gave at first a faint citron band spectrum, evidently due to impurity; on repeating the purification several times I at last succeeded in obtaining a white earth which gave only the merest trace of citron band spectrum. Its hydrogen equivalent, 58·0, and its chemical properties showed that it was probably Marignac's ytterbia. Subsequent experiments satisfied me that this earth did not contain more than one ten-thousandth part of yttria. The extreme tediousness of the chemical operations necessary to obtain this high degree of purity, and the long time they required, prevented me from pushing these results beyond what was necessary to prove the special point at issue.

The yttria, purified as already described, might still contain traces of terbia, together with erbia, holmia, and thulia. These were gradually removed by the fusing nitrate process. The atomic weight gradually got down to 31·0, but the spectra did not vary very much; that from the earth of lowest atomic weight being, however, the most brilliant.

Pure yttria is quite white. That from gadolinite, on testing in the radiant matter tube, gave a spectrum absolutely identical with that given by the zircon, cerite, thorite, orangite, and samarskite yttria. Pure yttria was also prepared from yttro-tantalite, euxenite, tyrite, and also from plaster of Paris and common limestone. In no case could I detect any difference in the position or intensity of the lines shown by their phosphorescent spectra.

THE PHOSPHORESCENT SPECTRUM OF YTTRIA.

The spectrum shown by pure ignited yttric sulphate in a radiant matter tube is one of the most beautiful objects in the whole range of spectroscopy. The spectrum is best seen under low dispersion and not too narrow a slit. It consists essentially of a broad red band, an intensely brilliant citron band, and two almost equally brilliant green bands. Other fainter lines are also seen, but they are not characteristic. Colored drawings and maps of the spectrum to scale accompany the paper. This description applies to the spectrum shown either by pure yttric sulphate or by an earth tolerably rich in yttria. When traces are present, the citron band only is seen. A little more yttria brings out the first and then the second green band, and finally, as the proportion of yttria increases, the red and blue bands appear.

The paper next gives a description of experiments made with pure yttria, and with various compounds of it, to see which would give the most characteristic spectrum. The sulphate heated to redness was found to give the best results. Pure yttria precipitated by ammonia did not phosphoresce in the slightest degree, and, necessarily, no citron band spectrum was to be seen. The yttria was removed from the tube, converted into sulphate, heated to redness, and again tested. This time it gave the citron band magnificently. This shows what apparently trivial circumstances will alter the whole course of an investigation. In 1881, when searching for discontinuous phosphorescent spectra, I tried a similar experiment with pure precipitated yttria, and entirely missed its citron band spectrum. Had I first treated the yttria with sulphuric acid instead of testing the earth itself in the radiant matter tube, the results would have been very different, and this research would probably have never been undertaken.

Yttria was now prepared by igniting the precipitated oxalate at a red heat. On testing it in the radiant matter tube it phosphoresced with feeble intensity, the light being about one-twentieth of that given by the ignited sulphate under similar conditions. The citron band was almost as sharp as the sodium line, and was shifted one division toward the blue end. The two green bands were visible, but very hazy and indistinct, and only to be resolved into bands with difficulty.

It is an old and probably a true saying, that every element could be detected everywhere had we sufficiently delicate tests for it. Early observations had prepared me for the wide distribution of yttrium, and no sooner had the exquisite sensitiveness of this spectrum test forced itself on my notice than I sought for yttrium in other minerals. The facts which I had noticed in connection with the variation of the appearance of the citron spectrum, according to the quantity of yttrium present, showed that it might be possible to devise a process for the rough quantitative estimation of yttrium, and after several experiments a spectrum test was devised sufficiently delicate to detect one-millionth part of yttria in a mineral. A table is given showing the results of this quantitative spectrum analysis, from which it is seen that among other substances pink coral contains one part of yttrium in 200 parts; strontianite, one part of yttrium in 500 parts; chondrodite, from Mount Somma, one part in 4,000; calcite, one part in 10,000; ox bone, one part in 10,000; an earthy meteorite (Alfianello), one part in 100,000; and tobacco ash, one part in 1,000,000.

ORIGIN AND FORMATION OF METALLIFEROUS DEPOSITS.

A RECENT lecture by M. Dieulafait before the Association Scientifique de France, upon the origin and formation of metalliferous deposits, is both suggestive and, in view of the prolonged discussions over this subject, extremely interesting.

After an introduction defining the physical characters of veins and metalliferous formations, in which he classifies rocks as belonging to the lowest and oldest strata, metamorphic, to the intermediate and latest strata, sedimentary, and to the eruptive or volcanic rocks, he proceeds to state his conviction that the action by which saline and gypsiferous beds have been formed, namely by evaporation of sea-water in isolated basins, will, somewhat modified and enlarged, afford a satisfactory solution of many of the problems connected with the origin of metalliferous deposits. In other words, he is inclined to exclude almost entirely all hypotheses which assign the contents of veins, etc., to a subterranean and deeply seated source, preferring to regard the terrestrial waters as the final source whence they were gathered and concentrated. Now he recurs to the prevalent association of quartz and baryta in mineral veins, and inasmuch as the former is a crystalline product which as yet has not been formed artificially except at high temperatures and under excessive pressures, and the latter is supposed to exist in almost imperceptible quantities in the country rock throughout the regions where veins occur, it was necessary to show that quartz is formed under ordinary conditions, and that baryta is universally distributed through the rocks composing the earth's crust.

M. Dieulafait considers the minute crystals of quartz in the grooves made by recent glaciers upon their bounding walls as sufficient evidence that quartz in a crystallized state can be formed under normal pressures and ordinary temperature, and cites his personal examination of 900 rocks taken from the entire thickness of the primordial formations in which he finds baryta in considerable quantities.

"Thus," he says, "without asserting that the baryta could not have come from the depths of the earth, the results I publish and the figures that I have announced show that in the primordial rocks at this time we find an amount of baryta of which the baryta isolated in veins does not represent one millionth part."

But it is far from sufficient for his theory to establish, as he thinks he has done, these two facts. It was necessary to demonstrate that the various metals were themselves disseminated through the rocks, that in consequence these rocks were formed in a medium rich in metalliferous combinations, that such metalliferous products could become separated from the strata during the formation, and that, in the second place, the stata forming the crust of our earth can even to-day yield to common water traces of metals and also show that under certain conditions these metals can concentrate themselves sufficiently to become of industrial importance.

M. Dieulafait, without endeavoring to establish the presence of all the metallic elements in the rocks, was satisfied to prove his proposition by confining his search to a representative of each group as follows: 1st group, lithium; 2d group, barium, strontium; 3d group, zinc, manganese; 4th group, copper; 5th group, tin (results not yet published).

In these examinations he has subjected to analysis 1,500 rocks gathered from an area corresponding to at least one-half of the terrestrial surface of our globe. These results, he claims, were definite and detailed. His conclusion is that "the primordial formation, or the rocks derived directly from it, contains lithium, strontium, barium, zinc, manganese, copper. That to detect their presence it has never been necessary to employ more than 100 grammes of material, and in the majority of cases an average of 5 grammes has been more than enough."

He deduces from his results the fact that the metals disseminated through the rocks represent in quantity one million times the amount of metalliferous minerals, etc., isolated in metalliferous deposits. But this is not all. Besides metallic bases, he finds boric, phosphoric, and vanadic acids represented in the rocks, which also are frequent associates in mineral veins. He claims to have proved that boric acid is not of volcanic origin; but, on the contrary, was the result of the concentration of sea water; vanadic acid repaid his research with the most flattering consequences. The salts of vanadium are already of industrial importance, inasmuch as they are used in printing coal-tar colors on goods, and in the production of certain tints upon porcelain. These and other uses made its price high, but M. Dieulafait's studies proved its very general distribution among the sedimentary rocks, and this led to an investigation by MM. Osmond and Witz, which had the most surprising consequences. They showed that certain iron minerals on the borders of the cen-

*As it is at present doubtful whether the oxides of several of the metals in this table belong to the type M_2O, M_2O_3, or MO, I have, for the sake of uniformity and simplicity in calculating the values from the composition of their salts, by which these metals are chiefly discriminated, taken the type of oxide to be M_2O.

tral plateau of France inclosed considerable amounts of vanadium. Its preparation from this source followed, and to-day an annual yield of 60,000 kilogrammes of vanadic acid is the product of the works at Creusot alone. From this point we follow the author more closely, translating where necessary his own language.

All the substances which are found in the primordial rocks exist of necessity in the seas, since these have ground down the strata of the early formations forming the great series of rocks which extend from these primitive formations to the middle of the Triassic. Without doubt, the percentage of metalliferous bodies found in the sea is extremely small, but this does not affect the question, if it can be shown that there is a sufficient quantity to admit of the marine origin of mineral deposits, and the conditions can be shown under which in spite of their extreme state of dilution the metallic contents of ocean water could be deposited. Now there are two assumptions which can be made: first, that these metalliferous bodies were separated directly from the sea waters at various epochs in the state they are now found; or, secondly, that they were inclosed in the sedimentary strata at the time of the latter's deposition, and consequently leached out by the percolation of waters, and concentrated in veins and ore beds. Both may be illustrated. The author takes the cupriferous deposits of Mansfield to illustrate the former. The conditions found there are: 1st, the ore bed has a thickness of only a few centimeters; 2d, it covers an immense territory; 3d, it is parallel with the inclosing beds, viz., conformable; 4th, the copper salt is strongly impregnated with bitumen; 5th, numerous remains of fishes are embedded in the bitumen; 6th, the more numerous the fishes, the richer and more abundant the copper deposit; 7th, the copper ore has a complex composition containing silver, nickel, cobalt, and considerable percentages of vanadium salts. The geological substratum is an argillaceous sandstone, a sedimentary rock, pure and simple; the overlying stratum is a thin bed of magnesian limestone, not 4 meters thick.

This limestone is again covered by heavy beds of gypsum, which is mingled with salt. These saliferous deposits are again sealed in by later sandstones, and these by limestones. The author then unfolds the sequence of events this state of things typifies. In the first place, he recurs to his previous demonstration that the early rocks contained copper disseminated through them in very sensible quantities, and infers that by their degradation and removal more soluble compounds of copper were added to the ocean waters, in addition to those already dissolved in it. Then, aided by a thousand natural accidents, he finds that at Mansfield an arm of the sea has become isolated, in which concentration of the salt takes place, which rendered it uninhabitable for marine life, and entailed the death of all its previous occupants, as well as of those which from time to time were admitted to it through its unclosed connection with the ocean without.

This of course proceeded gradually, and while the concentration of waters was sufficient to kill the fish, it was not advanced enough to produce precipitation of gypsum. The fish died and sunk to the bottom of this semi-isolated basin, where, owing to the saliferous strength of its waters, their decomposition was slow and retarded.

The accumulation of gypsum and saline deposits had not yet commenced, as it is necessary for a volume of sea water to be reduced to one-fifth of its ordinary volume before these bodies are precipitated in quantity.

However, there was a disengagement of soluble sulphides from the slowly changing organic deposits, notably from the fish, which produced a chemical precipitation the more perfect and sensible as the concentration of copper salts had become more and more marked with the increased strength of the sea water. Then succeeded a period of more extreme evaporation and consequent concentration, ending in the laying down of beds of gypsum, and rock salt, and dolomite, over which again, upon a reopening of this basin to the renewed incursions of the sea, were deposited new strata of sandstone and limestones.

M. Dieulafait strengthens his view of the origin of the cupriferous deposits at Mansfield by pointing out analogous conditions prevailing in the salt marshes of Berre, near Marseilles, where there are a series of basins opening into one another, of which the waters are more and more saline as you pass from the first to the last. Though fish swarm in the outer basins, when they are carried by sudden tides into the inner ones, they die at once and sink to the bottom. In other marshy regions bordering the Rhone, gypsum and salt are deposited, and among the organic remains of such spots a fresh water fauna is found, as fresh water fish which have entered the fatal pool by tributary and accidental brooks or streams.

Again, M. Dieulafait instances the great Gulf of Karabogaz, which communicates with the Caspian Sea by a canal through which one current prevails, and in which fish perish in great numbers, becoming at first blind in the less saline waters of the approach, and dying when drawn further within the basin.

These facts explain to M. Dieulafait the state of the metalliferous deposits of Mansfield, where the copper ore is thin and uniform, and thickest where the fish remains are the most abundant.

The copper, instead of being the cause of the death of the fishes, is its consequence. He extends the same reasoning to many other metalliferous strata, as the Permian of Russia and Bolivia, the Triassic and Permian of France.

The second assumption illustrated in this lecture is that the rocks, formed by sedimentation from seas, containing in a diffused state metallic bases, included in their deposition metallic salts. And the fact is stated, that dolomitic rocks, which, for reasons not as yet published, the author conceives are eminently marine, or laid down in seas which have undergone some concentration, contain almost universally, in large amounts, copper, zinc, and manganese. His chemical researches have demonstrated this conclusively, and they have been re-enforced by those of M. Boussingault.

The lecturer concludes in these words:

"When we examine from the standpoint of the geologist the associations of zinciferous minerals, we find them almost universally associated with dolomitic deposits. In many cases they are contemporaneous in their origin with the inclosing strata, but the masses concentrated in the crevices and cavities of dolomitic rocks generally have been formed posterior to the deposition of the rocks. Again, as the dolomitic rocks contain disseminated zinc, and are themselves especially dissolved away by water, it seems assured that most of their zinciferous minerals have been separated out by that means at ordinary temperatures and pressures. Which inference seems corroborated by the presence of the bones of Tertiary mammals in the zinc deposits found in caverns and pockets in the dolomitic beds. In fine, M. Dieulafait concludes that the saline bodies and metalliferous deposits have been both gathered from the rocks of the primordial formation through the agency of marine waters, that hence their origin is exterior and their formation conducted under ordinary conditions, that salt bodies are exclusively the result of evaporation, formed under influences that are active to day, but that ore bodies owe their existence to a combination of causes that share alike in their chemical, mechanical, and geological characters. The author disclaims wishing to assert, as indeed it would be obviously absurd for him to do, that thermal solfataric action or allied influences have not been the dominant or sole factors in the production of many metalliferous deposits, but only insists upon the important character of the agencies he invokes, and with especial reference to the cupriferous beds in the Permian strata."

L. P. GRATACAP.

CASSIA AND CINNAMON.

ALL kinds and qualities of cassia, imported into the United States, and doubtless also a portion of the cinnamon is indiscriminately designated cassia. Cassia lignea is what is denominated Chinese cinnamon in most European countries, and is produced in southern China in large quantities from the bark of a species of cinnamon tree. The bark, as it appears in commerce, is in small bundles of about one foot in length, weighing about one pound, and tied up with split bamboo and packed in mats of the same material. The tree producing this bark is said to grow with little attention, on land difficult of cultivation, and is therefore given up entirely to this spice. The bark of the branches only is used. It is stripped off by running a knife along each side of the branch and gradually loosening the bark, after which it is allowed to lie until the next day, during which time a slight fermentation sets in, facilitating the removal of the outer bark or skin, and the bark soon dries in the form in which we find it in the market. The quills bear a strong resemblance to cinnamon, but are thicker and harder, and rarely consist of more than two quills and show much less care in preparation.

Cassia vera also comes from China, and is really an inferior kind of Cassia lignea, or, more properly, it is the same kind grown wild. The Cassia vera which comes to this country is usually sent here from London, but is worth only two-thirds as much as Cassia lignea. A low grade of Cassia lignea and good selected Cassia vera, it would be difficult to distinguish one from the other, and so also would a fine and carefully selected lot of Cassia lignea and a poor quality of Ceylon cinnamon.

Ceylon, or true cinnamon, is produced by a small evergreen tree of several varieties, which grows at a considerable elevation on the island of Ceylon. The cultivation of the best kinds is restricted to a small extent of territory, the amount produced therefore being small, and consequently the price realized is always high compared with that obtained for the best grades of cassia. Much of the cinnamon produced on the island of Ceylon is of an inferior quality, but it all meets with a ready sale at varying prices. The best true cinnamon, unlike Cassia lignea and Cassia vera, is not taken from the branches, but from shoots, and even this is classified according to the part of the shoot from which the bark comes. Thus the bark from the end of the shoot is called second sort, that from the base third sort, and that from the middle first sort. There is also much care taken in properly drying and preparing the finer qualities for market. The best grades are in quills about thirty-eight or forty inches in length, and are made up in bundles of various weights, varying from five to thirty pounds.—*Oil, Paint and Drug Reporter.*

COCOA-NUT FIBER.

WITHIN the last twenty years a vast extension of the economic uses to which this valuable fiber is put has taken place. The term "coir," usually applied to this material, is the Anglicized form of the South Indian "kayaru," cord or twine, and is not applied in India to the raw fiber, which is called in the Tamil language "savuri." The fibrous husk or rind of the cocoa-nut is easily stripped from the nut while yet green, by striking it on the point of an iron spike, and then it is steeped in salt or brackish water, where it lies for several months, until the softer portions of the husk rot away, and the strong fiber alone remains. This is taken out, beaten with a stick to separate and clean the fiber, and twisted with the required number of strands into rope, or woven into matting, while the stiffer fibers are made into brushes and other articles of domestic utility. The fiber is pressed for shipping into bales weighing two hundred pounds each. The attempt has been made to prepare the fiber from the dried husk in England, but without success.

Much of the coir fiber used in England is brought from Ceylon; but a large and increasing quantity is now exported from Bombay and the Western coast of India. The supply is not inexhaustible; but as prices rise, cultivation is encouraged, and as the growth of this palm is along the sea coast, where other crops cannot be grown, the trade is a profitable one.

Factories for the weaving of coir matting have been opened by English and American firms at Allepy, Quilon, Colachel, Cochin, etc., and turn out a considerable quantity of goods. Spinning is not attempted here, being more cheaply done by hand at the places where the fiber is produced. Along the coasts of the backwaters and canals many people may now be busily engaged in scraping and cleaning the fiber and twisting it into yarn. In the factories the yarn is first sorted to its various shades and qualities. The warp is made by boys running backward and forward, then it is flattened and smoothed for weaving by being run through heavy rollers. The weaving is laborious work, performed by men who earn two or three rupees a week at it. The web is again rolled to give it some finish, wound securely in a roll, and marked.

Large profits have been made in this manufacture in India. But it can now be carried on so much better in England, with the machinery and appliances available here, that large quantities of the yarn are exported. One firm in Lancashire have introduced steam loom weaving of this material. The various shades of fiber—cream-colored, reddish brown, and blackish—which vary greatly according to care and skill in preparation, are first carefully separated, and cocoa-nut matting is now made of fine quality, with pretty shades of color and in pleasing patterns, so as to be available for higher uses than the very coarse makes, and the material is most durable. The yarn is also plaited by machinery into cinnet or belting.

Cables made of coir bear exposure to salt water better than anything else, the tannin which it contains preventing the fiber from rotting; they are exceedingly light and buoyant, as well as elastic. Coir cordage, in Dr. Wight's experiments, broke at 294 lb. weight. Even the refuse and broken fiber can be turned to account for stuffing mattresses, and is used in horticulture, etc., as no insect will touch it.

The exports from Travancore of this material form a large portion of the trade of the district, and amounted, in 1879–80, to nearly 150,000 cwt., valued at 13¾ lacs of rupees (say £137,200), and paying to the government a duty of 68,000 rupees. Of the cocoa-nuts themselves, nearly 9,000,000, valued at nearly 260,900 rupees, and paying customs duty 13,000 rupees, were sent away. Other products of this palm exported, as oil and copra or dried kernel, were valued, the former at 322,100 rupees, and the latter at no less than 26½ lacs of rupees, making a total value of the export of products of the cocoa nut palm, from Travancore alone, of 46¼ lacs of rupees (nearly half a million sterling). Some thousands of tons are also exported from Cochin.

Cocoa-nut fiber is so durable, useful, and economical a material that a great future is assured for the industry; and, as prices rise, the natives will pay increasing attention to the collection of the whole amount produced, and to its careful preparation. Perhaps when, through increasing demand, the fiber becomes still more expensive, it may be found possible to prepare it of greatly improved quality and appearance by steaming or boiling, so as to avoid the pollution of ponds and backwaters by the decomposing pulp of the husk, and the consequent blackening of the fiber so often observed. The textile ingenuity of the present age of invention may perhaps devise some additional uses for this fiber; hats and bonnets made of this material have, it is said, attracted much attention.—*The Colonies and India.*

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TABLE OF CONTENTS.

PAGE

I. CHEMISTRY AND METALLURGY.—On the Action of Chlorine on Certain Metals 6291
On Radiant Matter Spectroscopy; a New Method of Spectrum Analysis. By WM. CROOKES 6292

II. ENGINEERING AND MECHANICS.—The Concentrating Mill at the O'Neil Mines, Galena, Kansas.—3 figures 6293
Improved Compressing Machine.—1 figure and table showing reduction of various materials by consolidation 6293
The Jointing and Testing of Gas Mains. By C. W. FOLKARD 6293
Ancient Spherical Clock.—3 figures 6294
Elastic Wheeled Traction Engine.—4 figures 6295
Rarefied Air as Motive Power 6295
High Speed Boats.—2 figures 6296
Twin Screw Shallow Draught Steamer.—9 figures 6295
Proposed New Tunnel under the Thames, London 6296

III. TECHNOLOGY.—On Some Modern Systems of Cutting Metals. By W. FORD SMITH.—Tool holders and cutters.—To produce a maximum amount of cutting in a minimum of time.—Manner of grinding and apparatus therefor.—Hardening of cutters.—Twist drills.—Manner of making and grinding.—Test of accuracy.—Milling; old and new systems.—Setting of cutters.—Shape of Cutters.—Numerous figures and table giving comparisons of time used in roughing out and finishing metal surfaces in machine tools 6279
Cocoa Nut Fiber.—Preparation and use 6294

IV. ARCHITECTURE.—A House Costing $2,500.—3 engravings and plans of different floors 6287

V. ART.—Atmosphere and Space in Painting. By G. A. STOREY.—Artistic faculty.—Advantages of art study to the art patron.—Impression made by the art of painting.—Perspective as taught by mathematicians.—The true paint perspective.—Importance of background.—The paintings of Herculaneum.—Color.—Tone.—Finish and distance.—Modern work.—Several diagrams 6287
F. Schaper's Restoration of the Hermes of Praxetiles.—Large engraving 6286

VI. ELECTRICITY, LIGHT, ETC.—Reichenbach and the Psychical Research Society.—Luminosity of the poles of a magnet 6291
The Luminosity of Non-Illuminating Gas Flames 6291

VII. ASTRONOMY.—Sir William Siemens on Solar Physics.—Temperature of the sun 6291

VIII. GEOLOGY.—Origin and Formation of Metalliferous Deposits 6288

IX. HORTICULTURE.—Cassia and Cinnamon.—Difference between them 6294

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